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JOURNAL

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ROYAL GEOLOGICAL SOCIETY OF IRELAND.

I.—ON A NEW GENUS OF FOSSIL FISH OF THE ORDER *Dipnoi*. By
RAMSAY H. TRAQUAIR, M.D., Professor of Zoology in the Royal
College of Science, Dublin.

[Read 14th May, 1873.]

AGASSIZ, after describing the intermaxillary bone of *Megalichthys*, makes the following brief statement regarding the fossil which is the subject of the present paper: "M. König possède une pièce détachée qui paraît être le même os."*

This "pièce détachée" is in the collection of the British Museum, and has lately been completely wrought out by removal of the remains of the matrix, in which it was imbedded. It was shown to me some time ago by my friend Mr. Henry Woodward, who expressed to me, at the time, his own opinion that it could not belong to *Megalichthys*, but that it was in all probability a new genus. In this opinion I entirely concurred, as it was at the first glance evident that it could not belong to the *Saurodipterine* group, of which *Megalichthys* is a member, although certain parts did exhibit a very brilliant punctated Ganoid surface, reminding us of the polished plates and scales of that genus. On the contrary, fragmentary as the fossil unfortunately is, its configuration shows that it must be closely allied to *Dipterus*, and must therefore be included in the order *Dipnoi*; the close relationship between *Dipterus* and the living *Ceratodus* and *Lepidosiren* having been already clearly shown by Dr. Günther.†

The specimen before us is, as aforesaid, only a fragment, measuring $1\frac{1}{2}$ inches in length by 3 in breadth, and is evidently the extremity of the snout of a very large fish, probably 4 or 5 feet long. It is of a somewhat semilunar form; showing a rough posterior margin where it has been broken off from the rest of the head; a superior arched ganoid surface, which has formed part of the upper aspect of the snout; an anterior margin forming the front edge of the upper lip; and an inferior excavated surface, which formed part of the roof of

* Poissons Fossiles, vol. ii. part 2, p. 91.

† Phil. Trans. 1871.

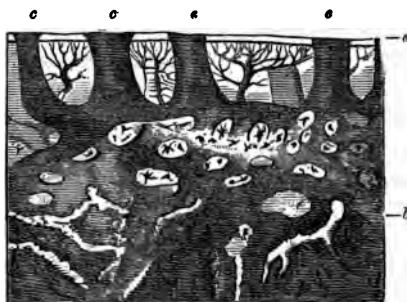
the mouth and nasal chambers. Placing the snout in its natural position, with the labial margin horizontal (Pl. I. Fig. 3), the superior surface is seen to slope downwards and forwards in the middle line at an angle of 45° , while towards the sides it is rounded off in an arched manner. This surface shows no trace either of sutures or of external nasal openings; it is smooth and ganoid, glossy and finely reticulate-punctate; near the labial margin, however, the minute punctures disappear, and are replaced by another set, which are larger, fewer, and further apart. Many of these larger punctures are also seen on the finely-reticulate surface above.

On turning up the fossil, and looking at it from below (Fig. 2), we see first a flattened margin, situated in front and laterally, which must have formed part of the upper lip, and which passes by a rounded edge over to the upper surface just described. This labial margin is brilliantly polished, and ornamented with the large scattered punctures already alluded to, and which average about $\frac{1}{10}$ inch in diameter. It shows also on each side and internally a pretty deep rounded notch, clearly indicating the position of an anterior nasal opening, which must thus have penetrated the upper lip as in the living *Dipnoi*. This arrangement also agrees perfectly with what is seen on the under aspect of the snout of *Dipterus*. The portion of the labial margin situated between the right and left nasal notches shows a faint median indentation, dividing it into two parts, and each of those parts, right and left, is set on its rounded posterior edge with a row of six small blunted tooth-like projections. Similar blunted tooth-like bodies are also seen on the inner aspect of the projecting portion of the labial margin behind each nasal notch.

Posteriorly and internal to this strange ganoid labial margin, the specimen is deeply excavated, and the surface here seen has evidently formed part of the roof of the nasal chambers on each side, and of the front of the roof of the mouth. The bone is here rough; no sutures can be distinguished; but the median longitudinal projecting portion evidently represents the front of the vomer, anterior to the attachment of the palato-ptyergoid plates. No trace is seen of vomerine teeth, as in *Ceratodus* and *Lepidosiren*, nor of their places of attachment as noticed by Günther in *Dipterus*; if present in this fish, they must also have been posterior to the portion preserved.

The hinder margin, all the way across between the two posterior angles of the specimen, shows nothing but the rough fractured surface where it has been broken off from the rest of the head. However, we may see here that the bone, forming the surfaces just described, exists as a rather thin shell over an internal space once occupied beyond doubt by cartilage, now completely filled up by the stony matrix, a dull grey argillaceous limestone. But the part between the posterior angle of the specimen, on each side, and the boss-like dentigerous projection behind each nasal notch, shows a distinct articular surface looking backwards, and which may have been for a maxillary bone, or for a superficial facial bone if the maxillary were wanting, as is the case in the recent *Dipnoi*, and apparently also in the fossil *Dipterus*.

A thin vertical slice, taken from the bone on the upper surface near the posterior external angle, displays microscopic characters essentially similar to those found in the scales and plates of many ganoid fishes, including also the scales of *Megalichthys*. The bone is here very thin, measuring only about $\frac{1}{10}$ inch in vertical section. Its microscopic structure is represented in the accompanying wood-cut. Immediately below the surface is an absolutely structureless layer of transparent ganoine about $\frac{1}{1000}$ inch thick. Through this



Vertical section of bone on the upper surface of the snout, magnified 48 diameters.

a Layer of ganoine.

b True bone.

c Punctures of the surface—opening into the canal system of the interior.

the punctures of the surface pass into a set of short vertical canals, each widening downwards so as to assume a rather conical figure. At their bases they are connected by horizontal tubes, and this system also communicates below with a close irregular network of ordinary Haversian canals, which ramify through the lower part of the section, and, becoming coarser below, cause the bone on its inferior aspect to assume almost a spongy appearance. The intervals between the set of short wide vertical canals, cup-shaped in the section, are seen to be each traversed by a vertical tube, which, coming up from the Haversian network below, soon divide in an arborescent manner into a great number of minute ramifying branches, which pass towards but not into the superficial layer of structureless ganoine. Adjacent trees of this kind also freely communicate with each other by means of arched branches, passing around and between the vertical canals between which their stems are situated. A beautiful kosmine-like layer is thus formed below the ganoine; it must be noted, however, that small lacunæ are occasionally seen among its minute tubules. In the true bone below, lacunæ of the ordinary type abound in the meshes of its Haversian network.

Unfortunately nothing is known regarding the geological formation, or the locality, of the fossil just described. To Mr. Davies, of the British Museum, I am indebted for the information, that it "formed part of the old collection of the British Museum, of which there are no records, hence its history as to from whom, and whence it came is wanting." Judging, however, from its general aspect, one might readily be tempted to infer that it was of Palæozoic age.

From the preceding description it is evident that the fish, to which

this strange and beautiful snout belonged, must take its place, not among the Ganoids proper, but among the *Dipnoi*. Of fossil fishes hitherto reckoned with certainty to the last-named order, we have only *Cheirodus*, *Dipterus*, *Ctenodus*, and *Ceratodus*; the position of *Phaneropleuron* and *Tristichopterus* being still doubtful. Our fossil is certainly neither *Dipterus* nor *Ceratodus*; *Cheirodus* is known only by its teeth; and as to *Ctenodus*, the front of the head has not yet been discovered, so that all evidence is wanting to connect it with that genus. It seems therefore, in these circumstances, best to frame a new genus for its reception; I propose, therefore, to bestow upon it the generic term *Ganorhynchus* (γάσος, ῥινχος), coupled with the specific name of *Woodwardi*, in honour of the distinguished palæontologist who first directed my attention to the fossil.

EXPLANATION OF THE PLATE.

- FIG. 1.—Upper surface of the broken-off snout of *Ganorhynchus Woodwardi*.
 FIG. 2.—Lower aspect of the same fossil, showing the ganoid and pitted labial margin, the anterior nasal notches, portion of the roof of the nasal chambers, and the broken-off vomer in the centre.
 FIG. 3.—The same fossil seen from the left side. At the posterior inferior angle is seen the articular surface referred to at page 2. Both of these surfaces, right and left, are seen in Fig. 2, at the posterior external angles.
 FIG. 4.—A magnified view of the smooth ganoid surface of the upper lip, showing the large scattered punctures or pits with which it is ornamented.
 FIG. 5.—A microscopic section of the ganoid bone on the upper surface of the snout. This drawing, executed in the absence of the author from Great Britain, does not convey a very accurate or intelligible idea of the microscopic structure; the woodcut, page 3, has therefore been substituted.

II.—MICROSCOPIC STRUCTURE OF IRISH GRANITES. By Professor EDWARD HULL, M.A., F.R.S., President R.G.S.I.

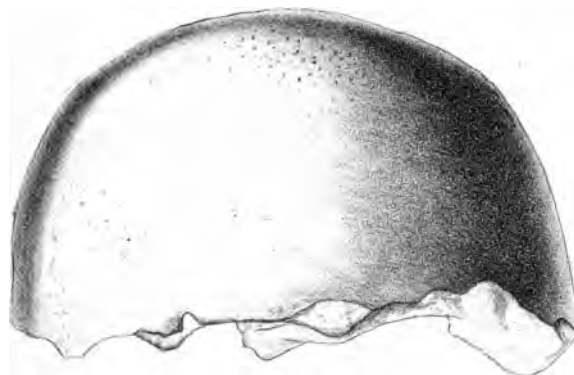
NO. 2. GRANITE OF AILLEMORE, CO. MAYO.

[Read November 11, 1873.]

THIS granite forms an isolated mass, rising into two eminences a few miles south of Louisburg, called Corvock Brack (1287 feet) and Knockaskeheen (1288 feet). It is a greyish granite—generally fine-grained—consisting of quartz, two felspars,—one orthoclase, the other triclinic, probably oligoclase—and dark green mica. In some places there are patches in which the felspar assumes the appearance of “graphic granite.” Numerous boulders of this granite are strewn over the district to the north-west, and on the south side of Knockaskeheen; the rock is traversed by regular joints ranging N. 10 W., along which it splits off into nearly vertical walls. The position of the granite is shown on Griffith’s Geological Map of Ireland, and it is surrounded by schistose beds, generally metamorphosed, and probably of Lower Silurian age. The granite itself is of older date than the Upper Llandovery beds, which lie to the southward.

Microscopic Slice.—The thin slice prepared by Mr. Jordan, of the Mining Record Office in London, shows the general structure of the granite extremely well. With the 2-inch object-glass, and under

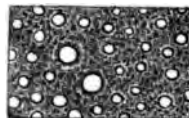
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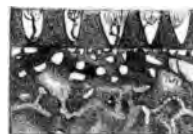
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3.



4.



5.

polarized light, its constituents are brought out in their relative proportions; the most abundant mineral being orthoclase, next silica, then the triclinic feldspar, then mica, and lastly magnetite. I shall now describe these minerals in the order above stated.

Orthoclase.—In the section this feldspar is often clouded and structureless, but is occasionally crystallized out into nearly perfect crystals, in which the angle of 90° between the sides may be frequently observed. But besides these there are several examples of the "cross-banded" feldspar, similar to that described and figured in my paper on the granite of Ffirbogh. These come out under polarized light, the bands crossing each other at angles approaching 90° . In one or two instances the banding takes a wavy form, and is only in one direction (Fig. 4). These various forms of this peculiar structure I regard as being characteristic of orthoclase, and I showed in my former paper on the Ffirbogh granite that they were due to a cellular structure along planes crossing each other at various angles corresponding with the planes of cleavage. The cases here observed are also referable to the same cause; but the cellular structure is scarcely so regular and well defined as in the case above referred to.

Triclinic Feldspar (Oligoclase?).—The fine parallel lines characteristic of the triclinic feldspars are observable in several instances, and are well brought out by polarized light. The crystals, however, are not nearly so numerous, nor are their forms so well defined as in the case of the orthoclase; sometimes, indeed, there is no crystalline form whatever, the feldspar occurring as an amorphous grain. An unusually well-formed crystal is represented in Fig. 5. It is slightly clouded.

Silica.—The silica, as usual in granites, forms the basis in which the other minerals (feldspar and mica) are imbedded. It is itself without crystalline form, receiving only the forms given to it by the sides of the feldspar crystals; and with polarized light the boundary edges are often seen lined by narrow parallel bands of different prismatic colours. The interior portions exhibit, on rotating the analyzer, the usual gorgeous shades of colouring, one colour sometimes imperceptibly shading off into another over the field of view, like the blending of the colours in a rainbow.

With the $\frac{1}{4}$ -inch object-glass the silica is seen to be highly cellular, and fluid bubbles in some of the cells come into view. With the No. 2 eyepiece, magnifying 350 diameters, the bubbles are well developed, and appear to occur in most of the cells (Fig. 6). Sometimes the cells are exceedingly irregular in form, sending out angular projections in various directions. The bubbles seem generally to occupy a large proportion of the cells, about one-third or one-fourth of the entire space, from which it might be inferred that the vapour from the condensation of which the bubble has been formed was not originally highly rarefied. Sometimes the cells occur in long slightly curved lines. Tubes and trichites are rare in the silica of this slice.

Mica.—With a high magnifying power the mica has a green colour,

and shows a wavy structure. It sometimes incloses black grains, which I have little doubt are those of magnetite.

Magnetite.—Some grains of magnetite undoubtedly occur, one of which is represented in Fig. 3. They are as usual opaque, and generally imbedded in the mica flakes. A few individuals, of which that above referred to is an example, are imbedded in the felspar.

NO. 3. GRANITE OF BALLYKNOCKAN, CO. WICKLOW.

The granite of Ballyknockan belongs to the great mass of the South-east of Ireland, which extends from Booterstown, near Dublin, to Poulmounty in Co. Carlow.

The Ballyknockan granite is considered by the Rev. Dr. Haughton, F.R.S., to be the best building-stone near Dublin. It has, according to this observer, a specific gravity of 2·636, and affords the following chemical analysis.*

Silica	...	...	...	...	...	70·82
Alumina	...	...	...	...	...	14·08
Peroxide of iron	...	...	...	...	...	3·47
Lime	...	...	...	...	...	2·65
Magnesia	...	...	...	...	...	0·31
Potash	...	...	...	...	...	4·64
Soda	...	...	...	...	...	2·31
Loss by ignition	...	...	...	...	...	1·39

—99·67

The admirable investigations of Dr. Haughton leave little to be added in the way of analysis. Nevertheless, the microscope reveals the presence of a second variety of felspar besides the orthoclase, which he and Professor Galbraith were able alone to infer from chemical examination. This second mineral, indeed, might probably have remained unobserved, except for the introduction of this new process of investigation.†

The rock from which the thin slices are taken is finely crystalline granular, and consists of a siliceous paste, inclosing white felspar, silvery-grey and black mica. With polarized light the felspar is seen to consist of orthoclase, and a triclinic felspar, less abundant but well defined; and the proportions in which the minerals occur may be thus arranged:—1. Silica; 2. Orthoclase; 3. Triclinic felspar; 4. Grey mica; 5. Black mica—the last occurring of a rich bronze colour.

Silica.—The silica occurs in an amorphous state, inclosing the other minerals, as is usual in true granites; but is itself composed of numerous individual patches, each refracting the light differently, so as to represent, on rotating the analyzer, a great variety of rich colours. The individual patches are generally separated by a fringe of prismatic hues, probably due to varying thicknesses of the section at the edges.

* Haughton, "Granites of Ireland," Quart. Journ. Geol. Soc. vol. xii. p. 177.

† Dr. Westropp, however, has detected a crystal of albite in the granite belonging to the same mass at Dalkey. Journ. Geol. Soc. Dub. vol. ii. new ser. p. 213.

With the $\frac{1}{4}$ -inch object-glass numerous cells of varying shapes and sizes come into view, together with some wonderfully long "trichites" ("trichiten," Zirkel) (Fig. 13); some straight, others bent or curved, and stretching through the mass in various directions. They are quite distinct from the tubes, and I have no good idea regarding their nature.

The cells are often disposed in lines, or along planes, perhaps concealed cleavage-planes. The cells for the most part contain fluid bubbles (Fig. 7), but they are only visible with a very high power; some, however, are "stone-cavities."

Along with the cells and stone-cavities are also to be observed, with a high power, very remarkable straight tubes (Figs. 8, 9, 10), terminated by rounded ends, and evidently hollow, or filled with gas. One of these (Fig. 10), remarkable for its length, seems to contain a very minute bubble near the centre, and another at the end of the tube itself. When first observed, I was at a loss to account for the formation of tubes of such length, straightness, and comparative thinness; but on showing the drawing which I had made of them to Prof O'Reilly, he at once pronounced them to be "tracks of gas bubbles," passing in certain directions through the silica when in a viscous state. I have little doubt that this is the true explanation of their occurrence.

Gas cavities (?).—A remarkable constellation of cells in silica, devoid of fluid bubbles, and which were, therefore, probably filled originally with gas, is represented in Fig. 10. In outline they are irregular, and when seen under a high power the uneven form of the walls of each cell gives rise to bright points, shading off laterally. When the light from the reflector is allowed to pass through the lower prism, the sides are seen to shade off internally in a series of faint but delicately defined concentric rings of prismatic colours, which art would fail to represent.

Orthoclase.—The orthoclase occurs generally in formless patches or in sub-crystalline forms, displaying with polarized light the "cross-banded" structure, very strongly pronounced (Fig. 12); the bands of colour intersecting at angles approaching 90° . This structure I have shown in a former paper to be due to planes of cells, corresponding with those of cleavage, intersecting each other at certain angles.*

Triclinic Felspar.—Judging from the analysis of Dr. Haughton, and the actual determination of the presence of albite in the granite of Dalkey by Dr. Westropp, which is part of the same mass, I have little hesitation in identifying the triclinic felspar which occurs in the Ballyknockan granite with albite. There are several small sub-crystalline forms in the slices, exhibiting with polarized light the fine parallel lines, and bands by which the anorthic group of feldspars may be distinguished; one of them is represented in Fig. 14.

Mica.—The silvery-grey mica occurs in the slice almost colourless

* Paper No. 1, Observations on the Microscopic Structure of Irish Granites. Journ. R. G. S. J. Vol. III. Part 3, p. 112.

to pale brown; the black mica as a deep bronze. The former, with a moderate power, is seen to be traversed by fine parallel lines indicating the planes of cleavage. The bronze mica with polarized light changes to black when the prisms are crossed; the colourless mica shows a rather faint play of colours on rotating the prisms.

In fine—the most noticeable features in the structure of this granite are the occurrence of a triclinic felspar, and the remarkable varieties of cellular structure in the silica.

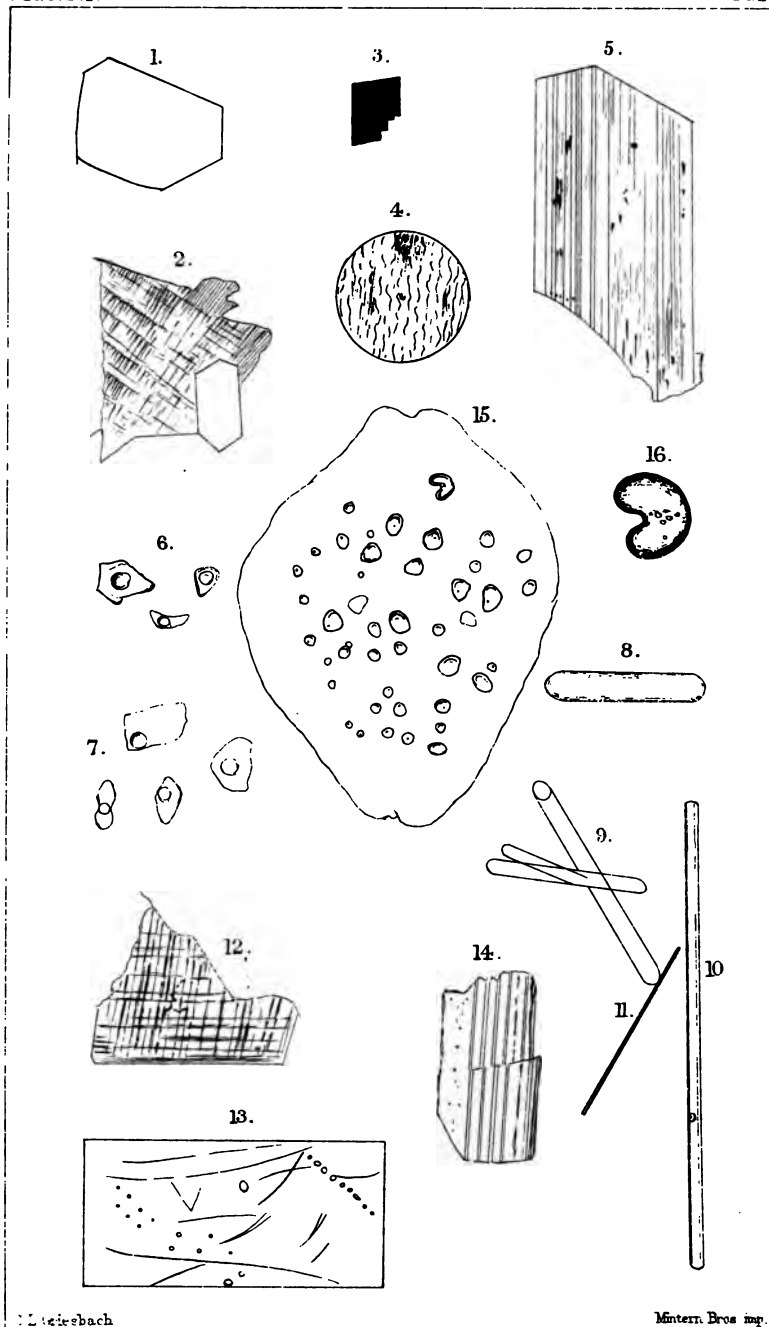
EXPLANATION OF THE PLATE.

- FIG. 1. Cross-section of felspar crystal. Granite of Aillemore.
 „ 2. Portion of crystalline grain of orthoclase, showing “cross-banded” structure. Magnified 25 diameters. Granite of Aillemore.
 „ 4. Portion of orthoclase crystal, showing wavy-banded structure. Magnified 25 diameters. Granite of Aillemore.
 „ 5. Imperfect crystal of triclinic felspar (oligoclase ?), showing fine parallel lines. Magnified 150 diameters. Granite of Aillemore.
 „ 6. Cells in silica containing fluid bubbles. Magnified 400 diameters. Granite of Aillemore.
 „ 7. *a. b. c. d.* Fluid cavities with bubbles in silica of granite. Ballyknockan.
 „ 8. 9. 10. Tubes in silica of granite. Magnified 200 diameters. Ballyknockan.
 „ 11. A belonite in silica. Magnified 200 diameters. Ballyknockan.
 „ 12. Imperfect crystal of orthoclase, showing “cross-banded” structure. Magnified 25 diameters. Ballyknockan.
 „ 13. Portion of silica, with cells, “trichites” and belonites. Magnified 200 diameters. Ballyknockan.
 „ 14. Crystal of triclinic felspar. Magnified 25 diameters. Ballyknockan.
 „ 15. Constellation of gas (?) cavities in silica. Magnified 40 diameters.
 „ 16. One of the cells. Magnified 300 diameters.

Abstract of Discussion.

The Rev. Dr. Haughton understood Mr. Hull to say that the second felspar in the granite of Aillemore was probably oligoclase. In connexion with the Donegal granites, Dr. Haughton would also infer that it would be probably oligoclasic. The question of the second felspar of granites was of great interest. The greatest investigator of these phenomena, the late Gustav Rose, believed that oligoclase was the second felspar in every instance. But the opportunities for investigating granites in Prussia are chiefly derived from the erratic boulders which have come from Scandinavia, where the second felspar in the granites is certainly oligoclase. This oligoclasic granite stretches also from Aberdeen through Donegal, probably to Mayo and Galway. But no one has found oligoclase in the Mourne Mountain granite; here the second felspar is albite. In Scotland we are somewhat puzzled, for in the Aberdeen granite both albite and oligoclase occur.

In reference to Mr. Hull's paper on the granite of Ballyknockan, Co. Wicklow, Dr. Haughton said that nineteen years ago Sir R. Kane and Prof. Sullivan found that the water of springs flowing from Ticknock contained more soda than potash; these gentlemen thought therefore that soda felspar must be present in the granite there.



Microscopic Structure of Irish Granites.

Figs. 1-6. Granite of Aillemore.

Figs. 7-16. Granite of Ballyknockan.

Messrs. Galbraith, Apjohn, and Haughton thought, on the other hand, that the greater solubility of the soda compounds might be the cause, though no more soda than potash were present in the felspar. It was found, however, that, excluding the orthoclase and mica, the paste of the granite contained a larger proportion of soda than was thought; the proportion of potash to soda being five to four, instead of six to one. Whence did this greater amount of soda come? It was reserved for Mr. Westrop to find a trace of a second felspar, crystallized in cavities, in granite quarried for Kingston Pier. The crystals in question were once thought to be fluorspar; but Mr. Westrop perceived that their angles were not right angles, and Dr. Haughton on analyzing them found them to be albite. The granites of Leinster and of the Mourne Mountains contain albite; these granites are essentially eruptive, and send veins into contiguous mica schist, even into limestone. Dr. Haughton believed the granites of Cornwall to belong to the same series, and to have albite, not oligoclase, as their second felspar. On the other hand, oligoclase is developed in the metamorphic granites of Donegal, Mayo, Galway, Scotland, and Scandinavia.

Mr. Symes said that the Rev. Dr. Haughton had made a mistake in classing the granite of Aillemore with that of Donegal and of the Ox Mountains. It was a truly eruptive granite, had not a trace of foliation in it, and sent veins into the surrounding rocks.

Mr. Hull having briefly replied to the observations on his paper,

The Rev. Dr. Haughton said that, although out of order, he might be permitted to make a few remarks in reply to Mr. Symes. He did not alter his general opinions on the subject; though he could quite believe that in Mayo, as does happen also in Donegal, some portion of the granite might have got completely melted and have thrown veins into the rest, and into surrounding rocks. It was the same rock only heated a few thousand degrees higher. Dr. Haughton believed that all granites were melted by pressure, and here some portion had only got a greater squeeze than the rest.

III.—NOTE ON A BED OF FOSSILIFEROUS "KUNKUR" IN THE PUNJAB.

By J. E. GORE, C.E., F.R.G.S.I.

[Read November 11, 1873.]

THE deposit of "Kunkur" occurs in the bed of a drainage about eight miles from the city of Puttiala Punjab.

The bed is about six inches thick, nearly horizontal, and lies about three feet below the surface of the ground. It is a soft limestone of Tertiary, or probably Post-Tertiary age, and is very rich in small fossil shells, which appear to be chiefly referable to the existing genera, *Planorbis* and *Limnæus*, the former being the most abundant. I have found specimens of *Planorbis*, of apparently the same species, in a river in the locality.

This is the only instance I have met with of "Kunkur" containing shells. There are many other deposits in the district, in none of

which I have detected any organic remains, although some of them, like the above, lie in the beds of drainages.

I may add that the "Kunkur" when burnt yields an excellent limestone, possessing hydraulic properties. The bed has been extensively worked for this purpose.

PUTTIALA PUNJAB,
3rd August, 1873.

IV.—THE LEINSTER COAL-FIELD. By J. McC. MEADOWS, F.R.G.S.I.,
Mining Engineer.

HAVING been connected with mining works in this district, the writer offers the following particulars in reference to its seams of Coal, and resources for supply of fuel.

The recent Royal Coal Commission estimated the quantity of Coal in the Leinster Coal-field at 75,000,000 tons. If only two-thirds or 50,000,000 tons be taken as practically available, the quantity is of some importance in connexion with the situation of the field.

Position and general description.

If a short journey by rail be made from the Kildare Junction of the Great Southern and Western Railway to Kilkenny, and from Kilkenny by the Central Ireland Line to Maryborough, and from Maryborough back by rail to Kildare, a complete circuit of the district within which the Coal-field is contained will be made. Surrounded on all sides by lines of railway, and although at some points very nearly approached, the Coal-field is, however, without direct railway communication with any of these lines.

Externally the Coal-district offers a generally uniform character. It consists of a succession of hills, varying from 600 to 1000 feet above the sea-level, which at or near their summits blend one into another, and together form in the interior a tract of undulating country extending over more than 200 square miles. The rivers Dinan and Deehin form the principal drainage lines of the interior, and the fine valleys through which they run in their course to the Nore give a favourable approach from the direction of the City of Kilkenny.

The greatest length from north to south is upwards of twenty miles, and the greatest width about fifteen miles, the northern portion of the field being in the Queen's County, and the southern in the Co. of Kilkenny.

The geological formation consists of alternations of stratified sandstone and shale, forming together, in external shape, an irregularly rounded tract of hill-country, which rests upon the uppermost beds of the Mountain Limestone.

The lower strata of this formation for a vertical thickness of more than 1000 feet appear to be destitute of workable seams of Coal; and as for the most part these lower beds dip or incline moderately towards the interior, a considerable portion of the formation referred

to is met with in the exterior, which is devoid of workable Coal, although interstratified with a few thin seams six inches and under in thickness. For this reason, amongst others, out of the total area of 200 square miles comprised in the district, not much more than one-fourth represents in the interior the Coal-field proper, or that portion of the formation within which the lowest workable seams of Coal have been found.

The strata in general undulate, and on all sides finally dip or incline to one common centre. This centre is in appearance basin-shaped. and it forms the main Coal-basin of the Lordship of Castlecomer and Doonane, with the detached basins of Clough and Newtown.

In this paper these Coal-basins will first be referred to, and afterwards the seams of Coal in the exterior of the field.

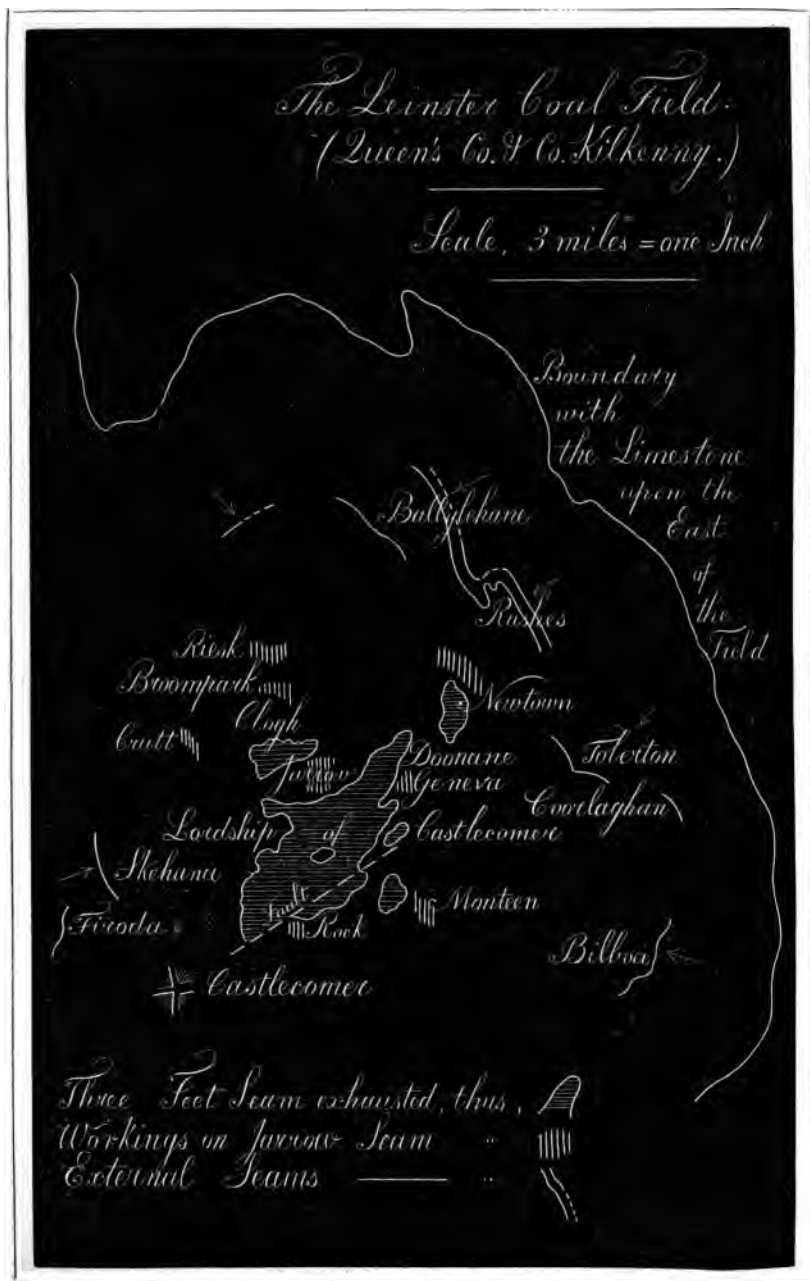
Interior of the Coal-field.

In these central basins once lay the celebrated "Kilkenny Coal." An exceedingly pure anthracite Coal, it varied from two feet six inches to three feet four inches in thickness, and is known as the three-feet seam.

Commencing at little more than a mile north-east of the town of Castlecomer in the Co. of Kilkenny, this seam of Coal extended into Doonane in the Queen's County, a distance of about four miles. Narrow at both ends and irregular in shape, the main central basin of the Lordship of Castlecomer had, however, from east to west, a maximum width of more than a mile and a half, and the entire area was favourably circumstanced for working, as the seam lay at comparatively shallow depths below the surface. The pits or shafts seldom exceeded sixty yards in depth, while the majority ranged from twenty to forty yards each.

With the exception of the northern end at Doonane, this central basin forms part of the Lordship of Castlecomer; and it may be said that the system of working by a number of small pits which was adopted more than 150 years ago, on the opening out of the seam by the then Sir Chr. Wandesforde, continued to be followed until its exhaustion within the last 25 years. During that period this seam of Coal was generally worked by the successive proprietors of the estate upon a system of contract with tenants and others, under one general engineering superintendence and management.

In addition to this principal basin, there lay two smaller basins of the same seam of three-feet Coal immediately near it. One was the Clough Colliery on the west, and the other that of the Newtown Colliery on the north. At one time, all formed a single basin; but owing to undulations of the strata and subsequent denudation, these smaller basins are now found detached. With the exception of some portions of the seam which were left in the Clough Colliery, owing to insufficient power for keeping the workings unwatered, the three-feet seam has been for several years past also exhausted in these two basins.



The total quantity of Coal obtained from this seam of Coal may be estimated at about 14,000,000 tons.

That source of supply having been exhausted, inquiry will next be directed to the other resources of the field.

About the year 1810, and subsequently, the existence of a seam of Coal below the three-feet seam was ascertained by borings made under the direction of the late David Aher, C.E., then manager of the mines of the Lordship of Castlecomer, in portions of the Coal-field that lay between the principal basin of the three-feet seam on the east and the Clough Colliery on the west, in ground into which the three-feet seam did not extend. Upon the site of one of these borings, on the lands of Cloneen, a shaft was sunk about the year 1829, under the direction of the late Matthias Dunn, and was called Jarow, after the Jarow Colliery in the North of England.

In this shaft, at a distance of about sixty yards from the surface, a seam of anthracite Coal was found, in appearance and structure widely different from the three-feet seam. When in its best condition, it has a thickness of about four feet, and it is called the Jarow or four-feet seam. Of this thickness of four feet, however, usually more than one-half consists of inferior Coal, the remainder being clean hard Coal of excellent quality.

It is irregularly massive in shape, sharp at the edges in fracture, and somewhat uneven or granular on the surface. Slow to kindle, but once fully ignited, it gives out much heat, and lasts for a considerable time, sometimes for hours together, without requiring attention or renewal.

While the three-feet seam of Coal could be had, the working of the Jarow seam was not carried on with vigour; but of late years considerable quantities of this Coal have been raised, and this seam is now reputed to be the most important and valuable in the district.

About the year 1861 the further working of the first or No. 1 Jarow Pit was discontinued, and a second shaft called the No. 2 Pit, about seventy yards in depth, was sunk more to the dip of the seam. Subsequently the original shaft was re-opened, and Coal is now raised from both.

In addition to these workings, the sinking of a third or No. 3 Jarow shaft upon the same seam is at present in progress.

From the workings that have been made, this Jarow seam is found to be variable in its thickness. In its bed it lies in easy undulations of the strata, and in the interior of the field it has its greatest development of four feet in thickness, principally in the deepest portions of these undulations.

When, however, it rolls over or rises towards the surface with the gradual ascent of the strata, it has been found generally to decrease in thickness, and sometimes to thin out to one-half or less than that in thickness.

From borings that have been, from time to time, made upon the royalties of the Lordship of Castlecomer, in addition to the workings already mentioned, its extension and continuation under the whole area that was once underlaid by the three-feet seam, may be

said to be now well established. The Jarrow seam is, in fact, the first workable bed of Coal which is met with below that seam.

Some of the borings that have proved this seam were made through pits in which the three-feet Coal had been worked. The thickness of strata between both seams may vary from seventy to eighty yards.

When it is borne in mind that there has not been as yet any working upon the Jarrow seam at any point under the three-feet seam, and that such workings as have been made upon it are all of them outside of the croppings or outgoings of that seam, it becomes evident that the Jarrow seam is likely to prove a principal source of supply of Coal in the future working of the field.

When circumstances shall call for a large development of its coal resources, the first step for that purpose will be taken when sinkings shall be made to the Jarrow seam through some of the deep portions of the principal basin of the three-feet seam.

In addition to the workings already referred to, the Jarrow Coal was, for some time, worked at Massford, and it is at present worked at the Rock Colliery, both near Castlecomer. More than eighty years ago its outgoing was discovered eastward of the Doonane portion of the three-feet seam, and some workings were then made upon it, and within the last twelve years at the Geneva Colliery, near Crettyard.

Its extension into Clough, the estate of George Leopold Bryan, Esq., M.P., was ascertained by the position and lie of the seam in the No. 2 Jarrow Pit, and works are in progress, and a shaft is now being sunk to that seam upon the Clough royalty.

At Monteen, upon the eastern side of the field, workings have been for some time and are at present carried on upon the Jarrow seam; but here it has been found upon the average to be not much more than from two feet to two feet four inches in thickness.

At the Hollypark Colliery, in the Queen's County, it has also been worked upon its northern verge or outgoing, outside of the outcrop of the three-feet seam of the Newtown basin. These works are in operation at present; but in this instance that Coal, as far as it has been as yet wrought, belongs to the class of a thin seam.

Upon the west, the Jarrow seam has been partially worked upon its verge or outcrop at the Broompark and Riesk Collieries, with a thickness of about eighteen inches; but whether in the condition of a thick or a thin seam, it generally retains the character of a strong useful coal. It may be worth remark, that wherever this seam has been found to approach the surface, its condition has been that of a thin seam of Coal, usually of workable thickness.

Lower Seams and Exterior of the Coal-field.

To ascertain what workable seams of Coal lie below the Jarrow seam, a useful point for observation will be found anywhere at the Newtown basin of the three-feet seam. There in its best condition a tract of that seam once lay, and if a line of section be now taken to the north of the Rushes School-house—a prominent feature at this part of the field—the structure of the district generally will

present itself. Advancing forwards from the Newtown basin, the Hollypark Colliery is met, in which the underlying Jarrow seam has been partially worked along its verge or outcrop, as already mentioned, although in the condition of a thin seam only; and passing from it, at a distance of less than one mile, the Rushes Colliery is next met with, in which the Rushes seam of Coal, about eighteen inches in thickness, was worked several years ago.

This Rushes seam is the principal Coal-seam of the exterior of the field. At Clogrennan Hill (Bilboa), upon the east, at Ballylethane or Modubeagh, and Mullaghmore upon the north, and at Skehana and Firoda upon the west and south, this seam has been partially worked, and these workings may be taken as its principal landmarks. Around the district it varies from fourteen inches to two feet in thickness, and it may be called, upon an average, an eighteen or twenty-inch seam. It is softer than the hard Coal of the interior, and the seam sometimes consists in part of fine Coal or Culm, with thin bands of clean Coal. It is quicker in kindling, but does not make so lasting a fire as the hard Coal. The only mining works that have been of late undertaken in the exterior of the field are those at Ballylethane or Modubeagh, where a shaft is being sunk to reach a portion of this seam at the north of the district.

Although met with and partially worked at several points, it is not meant to be conveyed that this Rushes seam is unbroken or completely continuous in the exterior, from one point to another. Owing to denudation, faults, and dislocations of strata, its continuity may be frequently interrupted, and from the same causes, it may be, in some places, altogether wanting.

Whatever its condition may be, it will, however, be found to underlie and to extend under the seams of Coal that have been already described in the interior of the field.

To complete the examination of the seams of the exterior, it remains to be mentioned that at a depth of about 60 yards below the Rushes seam of Coal, another is found which has been called the Rossmore Foot Coal, varying from ten to twelve inches in thickness. If the line of section be continued from the outcrop of the Rushes seam, the outgoing of this last-mentioned or Rossmore seam may be observed.

As at a few points Culm has been raised from this latter seam, although in very inconsiderable quantity, it may be considered, as far as present evidences extend, the lowest seam with any pretensions to be classed as workable in the Leinster Coal-district. The workings that have been made upon the Rushes seam and upon the Rossmore Foot Coal mark in part the principal points of the circumscribing line, within which the Coal-field proper is contained.

Before a complete section of all the workable seams can be given, that part of the field known as the Hill of Coolbane has to be noticed. It forms, in the interior, the steep hill or ridge upon the eastern side of the high road between Castlecomer and Crettyard, and is a special feature of the Coal-field.

The three-feet seam of Coal extended here to the foot of the hill,

and there, by a fault or dislocation of the strata which runs somewhat parallel with the hill, the seam was thrown down to a lower level. Owing in part to being so thrown down, but mainly to the steepness of the hill-side, which here rises quickly and immediately over it, there is here found overlying the three-foot seam a greater vertical thickness of strata than has been met with over that seam at any other part of the field. These strata contain in them three other workable seams of coal that are nowhere else found together in the field, but which obviously once extended over the entire area of the three-foot seam, before the land had been worn away and shaped as it is now found.

These upper strata extend, however, but for a short distance. Immediately to the east of them, and nearly parallel with the crest of the hill, one of the principal faults of the Coal-field strikes away in a north-east and south-west direction, bringing up to the south-east, within a few feet of the surface, the strata that contain the three-foot seam of Coal, and with them an extension of that seam upon the hill and the high ground behind it to the east and north, in the direction of Monteen and the Doonane river. The maximum displacement or throw of this fault is about eighty yards.

In the strata that have been referred to as forming the hill-side to the west of this main upthrow fault, in a thickness of less than seventy yards over the three-foot seam of Coal, the following section is found:—

	STRATA.		COAL.	
	Yds.	Ft.	Ft.	In.
Surface-soil and sub-strata	4	0		
Peacock, or 22-inch seam of Coal			1	10
Intermediate strata	15	0		
Stony Coal			3	0
Intermediate strata	7	0		
Double seam			2	6
Intermediate strata	36	0		
The three-foot seam			3	0

To these may now be added the other seams and strata, in descending order, viz:—

Intermediate strata, between the three-foot seam and Jarrow Coal, from 70 to 80 yards	70	0		
Jarrow Coal, from one foot to four feet in thickness, average			2	6
Intermediate strata, thickness not ascertained, but it may be from 150 to 200 yards	unascertained			
Rushes seam			1	6
Intermediate strata	60	0		
Rossmore Foot Coal			1	0

As far as present knowledge of the field extends, the foregoing section presents a fair classification of the several workable seams of the Leinster Coal-district. Seams six inches in thickness and under are omitted, as, although useful to the miner for the identification of particular beds, they are not of any commercial value.

Surveys of the District.

In the year 1814 a Geological and Mining Report upon the Leinster Coal-district, by Sir Richard Griffith, then Mining En-

gineer to the Dublin Society, was published by that Society. This Report was accompanied by an engraved map and sections, and after a lapse of more than sixty years since the survey was undertaken, the work done and the results arrived at form an enduring testimony to the abilities of Griffith, and to an earnestness of purpose that makes his labours upon that survey at such an early date a model of work for others. The main features of the structure of the field, as described by Griffith, have been followed in this paper, and the writer believes that they recommend themselves, upon their own evidences, to all who have had any practical mining knowledge of the district.

In the year 1859 the results of an examination of the Coal-field by the Geological Survey of Ireland were given to the public in the Geological Map-sheets of that part of Ireland, with sheets of sections and two descriptive pamphlets. The classification of the seams by that Survey is not in harmony with the results arrived at by Griffith.

For the general structure of the field, as given by him, and summarized in this paper, there is substituted a theory that the external workable seams do not underlie the seams of the interior, but that they re-appear, and that the seam which was worked at the Rushes and Clogrennan Hill formed in the interior of the field the three-foot seam of Coal. There are difficulties in the way of an acquiescence in this theory,—and they are not lessened when it is found that the Coals worked at the Geneva, Monteen, Riesk, and Moyhora Collieries are also classed by that Survey as belonging to the three-foot seam.

In contrast with the conclusions arrived at by the Geological Survey, it is only necessary to refer to a comparison of sections of strata over the Rushes seam and the three-foot seam, to show that such conclusions are open to re-consideration.

At Tilly's Pit on Ballylethane, upon the Rushes seam, there is a sectional thickness of strata in the shaft of more than 90 yards, with only one intermediate thin unworkable seam of Coal in that section overlying the Rushes seam.

In the side of the Hill of Coolbane, however, there are found over the three-foot seam, in a sectional thickness of less than 70 yards of strata, three distinct intermediate workable seams of Coal.

These sections appear to be so deficient in elements of constructive identification, it is thought unnecessary to refer to the differences which are found in the strata themselves, or in the thicknesses and qualities of the seams of Coal.

In connexion with the structure of the field, as presented in this paper, reference may be made to the Slievardagh Collieries.

From the Leinster district the underlying limestone and the lower beds of the Coal-formation extend in a south-westerly direction into the Co. of Tipperary, and the formation is found to preserve its upper or Coal-bearing strata as it approaches the town of Killenaula. In the hills to the north of that town are the Slievardagh Collieries, and as the lower beds and the underlying limestone are continuous from one district to the other, some approximate similarity in the

relative positions and characters of the seams of both districts may be looked for.

The Slievardagh field has the advantage of regularity in its stratification, and the following is a section of the deepest portion of the field near its centre, at the Earls Hill Colliery :—*

	STRATA.		COAL.	
	Yds.	Ft.	Ft.	In.
Surface and uppermost beds...	20	0		
Parkenclea, or four-feet seam			4	0
Intermediate strata ...	37	0		
Clashacona Coal ...			2	0
Intermediate strata ...	10	0		
Hanley's Vein ...			1	6
Intermediate strata ...	30	0		
Crow Coal ...			2	0
Intermediate strata ...	47	0		
Main Coal ...			2	0
Intermediate strata ...	67	0		
Maher's Vein ...			0	8
Intermediate strata ...	170	0		
Second, or Upper Glengoose seam ...			1	8
Intermediate strata ...	43	0		
First, or Lower Glengoose seam, being the lowest workable seam in the Slievardagh district, varying from one foot to one foot six inches in thickness ...				1 3

As in this section there is an upper seam for which in the Leinster field there is a deficiency of strata over the Peacock Coal, the sections of the two districts will be best contrasted in ascending order from the lowest workable seam in each.

It is submitted that the No. 1 and No. 2 Glengoose seams of Slievardagh represent the Rossmore Foot Coal and the Rushes seam of Leinster, and that Maher's Vein and the Main Coal of Earls Hill represent the Jarrow seam and the three-feet seam of the Castlecomer field. The thickness of strata between the No. 2 Glengoose seam and Maher's Vein points to the distance, which is also felt to be considerable, between the Rushes seam and the Jarrow Coal.

When the sections are examined in detail, and the relative qualities of the seams compared by those with practical knowledge of both districts, other parallels, unnecessary here to refer to, will be observed. Amongst them, however, may be mentioned as common to both districts the character of the coal of the two lower workable seams in which Culm or fine coal occurs, and the preponderance of hard coal in the upper seams.†

Present Condition.

Upon a recent visit by the writer, the several mining works, at present raising coal in the district, were found to be as follows :

Upon portions of the upper seams,—Pits on the Hill of Coolbane.

Upon the Jarrow seam,—Jarrow Pits Nos. 1 and 2, the Rock Colliery, Monteen Colliery, Hollypark Pits.

* Geol. Survey of Slievardagh Coal-district, Sheet 146, and accompanying Memoir.

† It may be mentioned that a further examination of the Leinster Coal-field is now (1874) in progress by the Geological Survey of Ireland.

Upon the lower seams,—Skehana Colliery, Ballylehane, Tolerton, Rossmore, and Reevanagh.

In addition to the foregoing, some few pits are occasionally met with upon shallow portions of basins of the three-foot seam, for recovery of remnants of Coal that may have escaped the efforts of former searchers.

The present output of the Coal-field is at the rate of about 80,000 tons yearly. Of this quantity about one-half consists of small Coal and Culm, which are used for the burning of lime and bricks, and as fuel by the poorer classes. Sixty years ago, when Griffith made his Report, the output was estimated at about 170,000 tons yearly.

Character of the Coal.

All the seams are of the Anthracite class and entirely smokeless. The three-foot seam was a very pure coal, and in its composition almost entirely free from the pyritic or sulphurous intermixtures with which the other seams are more or less impregnated.

To persons not familiar with the use of these descriptions of Irish Anthracite coal, the gases given off in burning are disagreeable where there is not sufficient chimney draught for their removal, and for this reason, amongst others, the use of the coal for house purposes has not extended much beyond the belt of country in which, around the Coal-district, it has become long and well established as the local fuel. With those that have been accustomed to it, the disadvantage referred to weighs, however, but little when the high heating power and lasting properties of the coal are taken into account. For the drying of corn and of malt there is a good external demand for this coal, and as for these purposes the best and hardest portions are always selected, it adds to its other qualities capability of transport to long distances without much waste or loss.

The Mining Population.

About 600 persons, including men and boys, are at present employed underground in the several mining works. Of this number 270 are colliers, whose special work is the getting of the coal from its bed, and about 240 constitute the miscellaneous mining labour employed underground in bringing the coal to the bottom of the pits or shafts, and keeping the working places and roadways or levels of the mines in working condition. About 70 are able miners who are employed in the sinking of the shafts at present in progress in the district.

Speaking from experience, and taking into account the labours they undergo, the miners, as a class, are an intelligent and well-disposed body of men. Owing to the nature of their work, they do not, however, in general, enjoy the robust health of the mechanic or field labourer, and much yet remains to be done for their better well-being in life.

It is much to be desired that with the progress which now brings material comforts to most classes, improved dwellings may in future replace the almost comfortless abodes that are now pointed out to

the stranger as the miners' homes, and which for the most part give but doubtful shelter to families and men upon whom not only the district itself, but a large extent of country around it, is mainly dependent for convenient supply of fuel. In bringing the present paper to a close, the writer feels that he would but inadequately perform his task if he confined himself to the discussion of seams of coal, without reference to the men by whose labour they are made available, or without expressing a hope that with increased industrial enterprise, there may be henceforth coupled in this district a reasonable solicitude for the material comfort of the working miner.

In conclusion, the writer offers his best thanks to the several mining proprietors for aiding him in his inquiries, and enabling him to give, with accuracy, the condition of the field as regards its present output of coal.

V.—THE VOLCANIC HISTORY OF IRELAND. By PROFESSOR EDWARD HULL, M.A., F.R.S., President; Director Geological Survey of Ireland.

[Being the Anniversary Address delivered to the Royal Geological Society of Ireland, February 11th, 1874.]

I HAVE the pleasure of congratulating the Society on its prosperous condition after an existence of forty years, during which time it has numbered amongst its members men of the highest distinction in Science, and has been presided over by some of the most illustrious amongst the cultivators of Geology. In looking over the names of the first officers of the Society in 1833, I am rejoiced to see those of the Provost of Trinity College, Sir R. Griffith, and Professor Apjohn, who are still amongst us; and to myself it could not have been otherwise than a matter of high gratification to have been elected to an office which has been filled by such eminent men as the former Presidents of this Society.

But more honourable to the Society than even the names of its officers are the large number of excellent papers, bearing, though not exclusively, on the Geology of Ireland, which are to be found in the pages of its *Transactions*. It is the merit of the contributions which must stamp the character of a Scientific Society; and amongst all the Geological Societies—that of London only excepted—there is none which has produced so large a number of excellent memoirs.

Other Societies—especially those of Glasgow and Edinburgh—are now treading closely on our heels; and I would, therefore, venture from this chair to urge upon our members a little increase of industry in the preparation of papers founded on observations over various parts of the country. The geological questions and phenomena of Ireland are far from being exhausted, and still present materials for the industrious observer. I would, also, observe, that the arrangements recently effected by the Council with the Editors of the GEOLOGICAL MAGAZINE afford authors of papers read before this Society rare opportunities of extended circulation. By that

arrangement, all papers of merit, after having been read before the Society, and approved by the Council, will appear in the pages of the GEOLOGICAL MAGAZINE, and subsequently in those of our *Transactions*; thus guaranteeing to them the advantages of almost a double circulation.

Amongst the papers which have been read during the year 1873-4, I may be allowed specially to mention those of Colonel Meadows Taylor "On the Coal-fields of Central India," that of Dr. Mackloskie "On the Fossil Wood of Lough Neagh," that by Dr. Macalister "On the *Charopsis Hibernicus*," that by Mr. Hardman "On the Occurrence of Zinc in the White Chalk of Tyrone," and by Mr. Meadows "On the Leinster Coal-field"; and I take this opportunity of acknowledging the gift to the Society of a mounted sheet of "Griffith's Geological Map of Ireland," presented by our valued member the Rev. Maxwell Close, F.G.S.

In addressing you this evening, I have ventured to select as my subject, "The Volcanic History of Ireland," but shall preface what I have to say by a few preliminary remarks on the general characters of volcanic phenomena.

The earthquake and volcanic history of individual countries is one full of interest to the physical geologist. This history has been ably written in the case of Scotland by Professor Geikie, and for our own country it seems to be a subject not unsuited to the present occasion. It is, perhaps, less difficult to decipher the characters in which are inscribed the volcanic, than the seismic (or earthquake) history of any special region; for earthquakes, although generally, are not exclusively, confined to volcanic districts, and often pass over without leaving any traces of their action. The existence of faults, or displacements of the strata, are not always to be relied upon as indicating former earthquake action; and owing to the rare cases which have come under actual observation of the production of faults and their connexion with earthquakes, we are not in a position to speak dogmatically regarding their relationship. If volcanic action, during any special geological period, were necessarily connected with, or accompanied by, earthquake movements, and these again with faults in the strata, it would be impossible to account for such cases as the Carboniferous volcanic district of Limerick, in which faults are comparatively rare; or the more recent case of the north-east of Ireland, where most of the lines of fracture are of later date than the consolidation of the great sheets of lava themselves. In a word, whether we regard the Lower Silurian volcanic region of North Wales, so ably illustrated by Sedgwick and Ramsay, the west of Ireland, the Carboniferous volcanic regions of the south of Ireland or centre of Scotland, or the Miocene volcanic districts of the north of Ireland and west of Scotland, we are equally impelled to the conclusion, that the main lines of fracture are totally unconnected with the volcanic products, and belong to periods either preceding, or subsequent to, those of volcanic activity.

In attempting to determine those periods in the past history of

our globe in which volcanic phenomena have been prevalent, and the districts in which the products of volcanic action have been developed, we must guard ourselves against an error of observation into which we might be liable to fall by observing merely the greater or less proportion of igneous rocks in each case. There may be formations penetrated by numerous sheets and dykes of trap rock, none of which can properly come under the head of "volcanic," and which, therefore, present no true marks of contemporaneous volcanic action. Dykes of trap of an irruptive (or intrusive) character may belong to a geological period different from that of the strata in which the dykes occur; and it is often exceedingly difficult to determine their true age. Even in the case of sheets of trap, unless very careful observations are made regarding their relations to the strata which inclose them, much caution is required in determining the question whether they are volcanic or plutonic, or as the late Professor Jukes used to say, "eruptive or irruptive." While no truly intrusive rocks can be properly called "volcanic," it is clear that all volcanic rocks are to some extent intrusive; for wherever they occur in sheets amongst the sedimentary strata, they must in some part of their extension pass vertically or obliquely through the strata which are in course of formation. Such truly volcanic lavas may therefore present evidences of intrusive action amongst the beds which underlie them; but we may feel sure that the beds which rest upon them, belonging to the same formation, will be not only undisturbed, but remain generally unaltered in physical constitution.

But the most reliable phenomenon to guide the observer in determining the question whether or not true volcanic action has left its traces upon any formation, is the presence of beds of ashes, agglomerates, or other volcanic *ejecta*, which have been blown out of submarine or sub-aerial vents, and have subsequently become interbedded with the strata. For, while it is true that such accumulations may not necessarily be present at all times amongst volcanic rocks of different formations, they are, doubtless, very general accompaniments; and whenever they do occur, we may safely conclude that we are in the presence of truly contemporaneous volcanic rocks; that is to say, rocks which have been ejected in a liquid or fragmental state during the period of deposition of the strata in which they are found.

But, before entering on the consideration of the successive periods of volcanic activity in Ireland, one or two observations regarding the use of the term "volcanic" may not be unnecessary, in order to guard against misconception of my meaning. The term is generally exclusively applied to designate those rocks, consisting of various kinds of lava, ashes, scoriæ, etc., which are now from time to time being poured forth or blown out of active volcanos, or those which, like Auvergne and the Eifel, have become extinct in Post-Tertiary times. We have, therefore, *active* volcanos and *extinct* volcanos, with their respective lavas, etc.; but there seems no good reason why the term should not also be applied to those products of internal igneous action which have been erupted during the formation of

Cainozoic, Mesozoic, and Palæozoic rocks, and which are found interstratified with them. And as there are at the present day both sub-aerial and submarine volcanos, so, doubtless, there were in the past; and geologists are now becoming familiar with such expressions as volcanic rocks of Silurian, Carboniferous or Permian periods, and which, from the necessity of the case, must chiefly be the representatives of the sub-marine or sub-lacustrine classes of volcanos.

Guided, then, by such principles of determination, let us endeavour to review in the order of succession the periods which in this country present us with unquestionable evidences of volcanic activity, and we shall consider them under the three great divisions of geological time, the Palæozoic, the Mesozoic, and the Cainozoic or Tertiary.

Palæozoic Epoch.—The oldest rocks represented in Ireland—the Cambrian beds of the east coast—present us with no evidences of contemporaneous volcanic activity; but when we ascend into those of the Lower Silurian period, we have numerous examples of volcanic rocks in several parts of our island where these formations occur. Throughout the range of these beds in the counties of Wicklow, Wexford, and Waterford, there are numerous sheets of felstones and porphyries accompanied by beds of ash and volcanic breccia, interstratified with the slates and grits which for the most part make up the Lower Silurian rocks of those districts. These contemporaneous traps are referable to the acidic felspathic, or highly silicated felstone group; and amongst them are outbursts of hornblendic rocks, or diorites, as well as a few melaphyres, which are of intrusive origin and later date than the felspathic rocks themselves. The districts of Stradbally and Kill, near Waterford, seem to have been foci of volcanic action. Similar beds of porphyries, felstones, ashes, and agglomerates are of frequent occurrence in the Silurian district north of the valley of the Boyne, but become less frequent in the districts of Down, Armagh, and Cavan. As all the fossils yielded by these Lower Silurian rocks are of marine origin, we must suppose the whole series to be marine; and we may therefore infer, that the volcanic rocks of the period were erupted from vents sporadically breaking out over the sea-bed of the period, and either pouring forth sheets of liquid lava, or vomiting out masses of fragmental materials which were strewn over the bottom, and were in turn covered over by fresh sediment.

It is interesting to observe that these rocks are the representatives of those great sheets of felstone and porphyry which rise into the lofty escarpments of North Wales, and which have been so ably described by Sedgwick, Murchison, and Ramsay; and I am informed that the late Professor Jukes, when engaged with Mr. Du Noyer in mapping out these beds over the Silurian district of the south-east of Ireland, was constantly struck by the marked resemblance of the old volcanic rocks of this district to those with which he had become familiar amongst the mountains of Snowdon, Moel Wynn, and Cader Idris.

Contemporaneous trap-rocks being so abundant amongst the Lower Silurian rocks of the east of Ireland, where they are generally unaltered, it can scarcely be doubted that they are also represented amongst the beds of the same great series in the west and north-west of the island, where they have undergone, for the most part, various degrees of metamorphism. In the Galway district, Mr. Kinahan considers that such rocks may be recognized amongst the hornblende schists of the metamorphosed districts;* but while the general conclusion may be admitted, the great amount of alteration which these rocks have undergone, together with their structural complications, renders actual determination in special cases somewhat uncertain.

The Lower Silurian period may, therefore, be considered as having been one of great volcanic activity in this country, as well as in Wales and Cumberland; the products being, for the most part, felspathic and highly silicated, and such as were erupted at various points over the bed of the sea.

Upper Silurian Period.—The Upper Silurian rocks are not very largely represented in our island; nevertheless, they present unmistakable evidences of contemporaneous volcanic action. Nothing can be more conclusive on this head than the phenomena observable in the mountainous region of West Mayo and Galway. Here, on ascending the flanks of Muilrea from the north shore of Killary harbour, we cross over the edges of great beds of grit, slate, and conglomerate, alternating with others of quartz-porphyry, each bed capped by its covering of volcanic ash; as if showing, that after each successive outpouring of lava, there had been a grand eruption of fragmental materials from the volcanic vents. In all probability these vents, like those of the Lower Silurian period, were submarine, nor is there any very marked distinction in the general character of the volcanic products.

Another district of volcanic action of this period is that lying along the western shores of Lough Mask, where beds of feldstone, quartz-porphyry, felspathic ashes, and agglomerates are associated with fragmental strata, supposed to belong to the Upper Llandovery series, but which may also represent the earlier stage of the Muilrea volcanic rocks.†

The Promontory of Dingle, where it projects into the Atlantic Ocean, together with some of the Blasket Islands, affords evidence of having been another district of volcanic action during the Upper Silurian period. Great beds of ash, agglomerate, and a few of trap form the coast from Clogher Head southwards, for a considerable distance, and again are found at Beginish, Young's, and Inishvickillane Islands, and have been carefully laid down on the maps of the Geological Survey by the late Mr. Du Noyer.‡ The thickness of

* Mem. Geol. Survey, Explanation Sheets, 105 and 114.

† See Geological Survey Map, Sheet 85.

‡ Sheet 171. See "Explanation" of Sheets 160, 161, 171, etc., by Messrs. Jukes and Du Noyer, pp. 12, 46, etc. (1863).

these volcanic products has been estimated by the late Professor Jukes at 2,500 feet, and they are interstratified with sedimentary strata richly stored with marine fossils of the Wenlock stage. As the beds of felstone and ash of Muilrea probably correspond to this period, we have evidence of at least two centres of volcanic activity in the west of Ireland during the Upper Silurian period, which, for all we know to the contrary, may be but representatives of vastly more extended volcanic regions spreading either beneath the ocean, or beneath formations of more recent age on the land.

Old Red Sandstone Period.—The Old Red Sandstone presents us with several examples of contemporaneous volcanic rocks, both in the northern and southern districts. In the neighbourhood of Boyle, in Co. Roscommon, there occurs one or more beds of consolidated ash, interstratified with the red and purple sandstones and conglomerates of that formation.* In the southern district, one of the most remarkable and well-known cases is that which occurs amongst the Killarney mountains, south of Lough Guitane, and which has been admirably illustrated by the pen and pencil of Mr. Du Noyer, under the direction of Professor Jukes. Here, at Benaunmore, a bold rock reaching an elevation of 1,490 feet, a mass of columnar felstone indicates the position of an old "neck" or volcanic throat, from either side of which stretch, for considerable distances, beds of felspathic ash and agglomerate, with large "balls" of felstone, often hollow in the centre, which were probably bombs, shot out of the vent at various stages of eruption. These beds of ash re-occur at Lough Garagarry, Lough Managh, and the Devil's Punch Bowl, to the west of Benaunmore, and rise into the summit of Crohane (2,162 feet), and the southern slopes of Killeen mountain on the east.† To the south of this, there is another district, containing contemporaneous trap-rocks, forming the cliffs of Cod's Head and Dursey Island, at the mouth of the Kenmare river.‡

The shores of Lough Kay and Valentia Harbour present to us another striking instance of a volcanic centre of eruption during this period. Beds of greenstone, felstone, ashes, and agglomerates are here associated with those of Old Red Sandstone, and pierced by numerous dykes.§

Carboniferous Period.—The Lower Carboniferous rocks, both of the North of England, of Scotland, and of Ireland, afford examples of contemporaneous volcanic action of considerable intensity. The so-called "toad-stones" of Derbyshire, and the great sheets of melaphyre, porphyrite, and ashes of the central valley of Scotland, forming the Kilpatrick, Campsie, and Dalry Hills, appear to have been erupted over the bed of the same sea as that in which were poured out similar materials in County Limerick, forming the well-known Carboniferous volcanic rocks of "the Limerick Basin."

* Messrs. Jukes and Foot, Journ. Geol. Soc. Ireland, Vol. I. Part 3, p. 249.

† Maps of the Geological Survey, Sheets 184, 185, with "Explanations."

‡ *Ibid.* Sheet 198, with "Explanations," pp. 8, 17, etc.

§ *Ibid.* Sheet 182, with "Explanations," p. 26.

These rocks have been already so fully described by several observers, that I shall confine myself to a very short description, such as is essential to the brief history of volcanic action which I am here endeavouring to draw up.*

The trap-rocks of the Limerick Basin, ably described by Professor Apjohn, belong to at least two consecutive periods of eruption; both, however, included in the Carboniferous Limestone period, and are disposed in concentric sheets round a tract of Upper Limestone shale, which occupies a district around Ballybrood. The "Lower trap-band" is more important and continuous than the Upper, and along with beds of ash and agglomerate is found in several tracts to the north and west of the band itself. In several spots both to the north and south of the "Lower trap-band," are isolated bosses of trap, such as those of Knockdirk, Carnanagh Fort, Cullon, and Maddyboy, which may be regarded as the old "necks" or volcanic throats, from which the sheets of trap and ashes have been erupted or blown out, but from which they are now disconnected by denudation.

As regards the composition of these rocks, notwithstanding the variety of names they have received, microscopic examination shows them to belong, with few exceptions, to that series of old augitic lavas usually called "melaphyres," which have undergone considerable alteration from their original condition. The base is for the most part a triclinic felspar, in which are inclosed crystals of augite, olivine, and magnetite, together with chlorite, which must be considered of secondary origin. While such is the character of the generality of these Lower Carboniferous lavas, there are occasional variations; and in the case of the rock of Knockdirk we find a highly silicated felstone forming apparently one of the old necks of eruption.

Another interesting volcanic district referable to this period lies at the entrance to Bantry Bay, amongst the rocks extending from Black Ball Head to Bear Island. They consist of slates, grits, and calcareous bands belonging to the "Carboniferous Slate" and "Yellow Sandstone" series of Sir R. Griffith. The volcanic rocks associated with these consist of contemporaneous and intrusive felstones, greenstones, with beds of ash, breccia, and agglomerate, and are ably described by Messrs. Kinahan and O'Kelly in the *Memoirs of the Geological Survey*.† Amongst these certain actual vents of eruption are recognized by the authors referred to; and owing to the variety of volcanic phenomena here exposed in the fine coast-sections,—the beds of felstone, porphyry, ashes, and breccias; the old volcanic necks filled sometimes with trap, some-

* The composition of the Knockdirk trap is essentially so different from that of the other masses, that I suspect it to belong to an older period of eruption. See author's paper on "The Microscopic Structure of the Limerick Trap-rocks," *Journal R.G.S.I.* Vol. III. Part 3, p. 112.

† *Geol. Survey Map, Sheet 198, with "Explanations" to Sheets 197 and 198 (1860).* Also Mr. Kinahan on "The Igneous Rocks of Berehaven," *Journ. Geol. Soc. Dublin*, vol. vii.

times with fragmental materials; and the dykes which range both through the igneous and sedimentary rocks,—this district offers most instructive materials to the student of the volcanic phenomena of Palæozoic times.

As the upper portion of the Carboniferous Slate series, which expands into such unusual proportions towards the south-west of Ireland, may, with some probability, be considered as partly the representative in time of the Carboniferous Limestone, it seems highly probable that the submarine volcanos of the south-west coast just described were in active operation at the same period as the earlier ones of the Limerick Basin, and these again contemporaneously with those of the centre of Scotland and the north of England; so that this portion of the bed of the ocean—swarming as it was with coralline, radiate, and molluscan life—was at this period frequently invaded by sheets of augitic lava poured forth from submarine vents; and by showers of ashes, stones, and bombs, shot forth and strewn by the currents of the sea.

With these events the history of the Palæozoic volcanic eruptions of our island closes; and we have to ascend through a long lapse of geological time, including the whole of the Mesozoic epoch, before we again meet with evidence of contemporaneous volcanic action in Ireland.

Tertiary Period.—After the volcanic fires had slumbered throughout so many ages, they again burst forth in the Tertiary period with unwonted intensity over the area now occupied by the N. E. of Ireland, extending thence to the west of Scotland and the Inner Hebrides. In our own island the area now occupied by these volcanic rocks may be taken at 2,200 to 2,300 square miles. Yet this area, large as it is, is but a fragment (though doubtless a large one) of the original surface covered by augitic lavas, which once stretched as far south as the mountain ranges of Slieve Croob or Mourne, and eastward as far as the Sperrin Mountains in the County of Derry.

The volcanic rocks of the north-east of Ireland are clearly referable to three distinct periods of eruption—all, however, more recent than the Upper Chalk—and therefore referable to the Tertiary period. During the earliest of these periods, eruptions of highly silicated lavas, which have solidified into trachytes, rhyolites, and pitchstones, took place from several distinct vents—two of which, at least, have been determined. One of these is situated west of Hillsborough, amongst the Lower Silurian rocks, and the other amongst the hills north-east of the town of Antrim, at a distance of twenty miles from the former. At what precise period this eruption of trachytic lavas took place, we have no means of knowing; but as it preceded that of the overlying augitic lavas, which we know to have been of Miocene age, it is probable that these oldest volcanos were in activity as far back as the Upper Eocene period. Thus it would appear that the volcanic fires burst forth contemporaneously over the north-east of Ireland, and the region of Mont Dore in Central France, where the eruptions have been shown by Lyell and

Scrope to have taken place at this period. This earliest period of volcanic activity was followed by one of, we may suppose, prolonged repose, upon the close of which a second and more extended outburst of volcanic materials took place over the whole area, extending from the slopes of the Slieve Croob range northwards. The lavas of this period are essentially augitic, consisting of dark amygdaloidal basalts and dolerites often decomposed, and parted by bands of bole and red ochre, which were formed by decomposition of the upper surfaces of successive flows. The most southerly of the vents of this period seems to have been situated at Scrabo Hill, in Co. Down, on the south side of Belfast Lough, and many others, mostly hidden from view, are scattered over the surface of Co. Antrim. The sheets of lava poured forth from these vents in successive flows attained a thickness of 500 or 600 feet, and were accompanied by showers of ashes, after which there was a cessation of volcanic activity; and the second period came to a close.

It was during this period of repose that those remarkable and valuable beds of lithomarge and pisolitic iron-ore were formed, as I believe under the waters of a lake, or chain of lakes, several times larger than Lough Neagh. The streams which entered these lakes—strongly impregnated with iron—also carried down leaves and stems of plants which grew on the basaltic uplands along their shores. In other places plants actually grew over extensive lagoons, and beds of lignite were formed. The plants from these beds have been described by Professor Harkness, F.R.S.,* and more recently by Mr. W. H. Baily, from specimens obtained from the railway cutting of Ballypallidy,† by the late Mr. Du Noyer. The identity of these plants with those of Miocene age establishes the geological age of the basaltic lavas on which they repose, as also their coincidence in time with the basalts of Mull and the Inner Hebrides, first determined by the Duke of Argyle, with the assistance of the late Prof. E. Forbes.

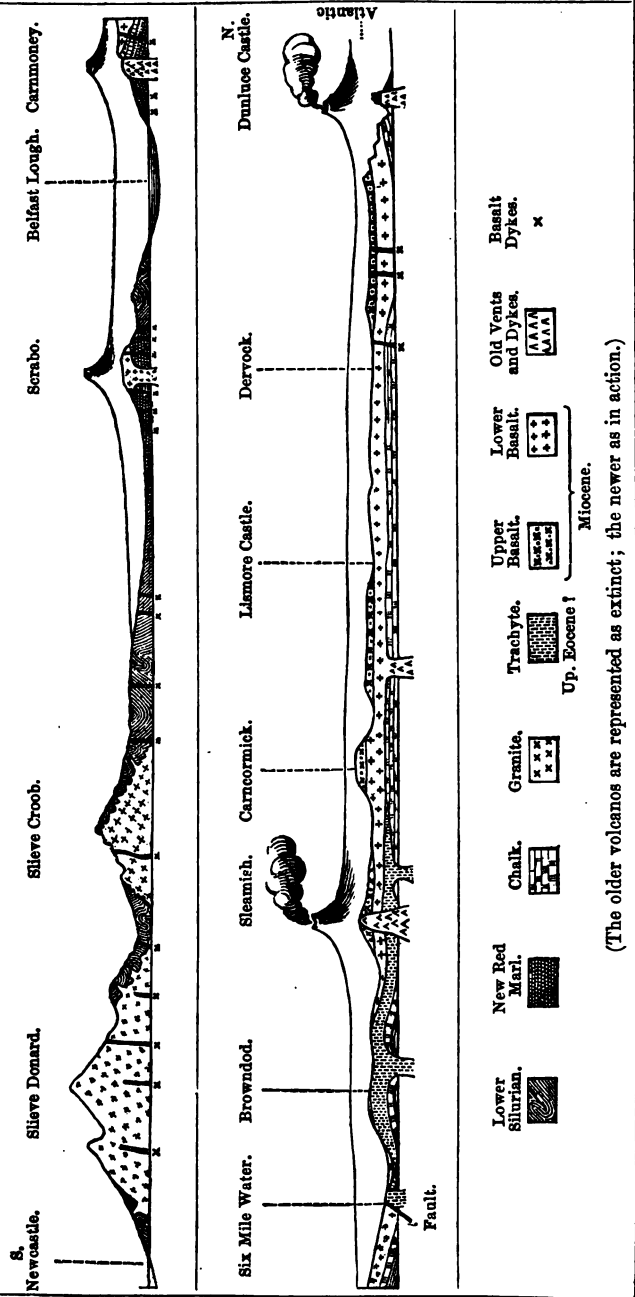
At the close of this period of repose a new outburst of volcanic activity took place, and great sheets of augitic lavas were poured over the older beds, to a depth of 400 or 500 feet in some places. Amongst the old necks or vents belonging to this third period, probably those of Dunluce, filled with large bombs, and of Sleamish, an abrupt isolated mass of basalt rising above the surrounding country, may be identified; but the craters have entirely disappeared, and we can only recognize occasionally the truncated throats by which they communicated with the interior of the earth's crust.

The third period of volcanic activity seems to have been accompanied or followed by the production of immense numbers of nearly vertical dykes—filled with basalt—which traverse not only the older sheets, but the newer. The production of these dykes seems to have been the result of the final effort of the elastic gases

* Brit. Assoc. Report, 1856, p. 66.

† Quart. Journ. Geol. Soc. Lond. vol. xxv. p. 357 (with plates).

SECTION FROM SLIEVE DONARD TO THE ANTRIM COAST SHOWING ORIGINAL AND PRESENT POSITIONS OF VOLCANIC ROCKS.



and steam which are the motive forces in volcanic eruptions. In order to account for the existence of these dykes—which would occupy a considerable area if placed side by side—it is necessary to suppose a general inflation or bulging of the earth's crust in this region. Such an inflation would be accompanied by the formation of fissures, which, when filled in with molten lava from below, would, as it seems to me, result in the production of the dykes to which I have referred.

The whole of the volcanic operations here briefly described appear to have been subaerial. If submarine—as has often been supposed—we might expect to have found marine strata accompanying some of the beds of lava; but these are altogether absent, and the various bands of red bole can be regarded as nothing else than lava, or volcanic ash decomposed in presence of the atmosphere. The microscopic structure of some of the more compact beds of bole bears out this view.

It is very remarkable, considering the comparatively modern period of these volcanic phenomena, that, as far as we know, none of the original craters are to be found over the whole region. Here and there, indeed, we find the pipes or throats of the old volcanos, but the original craters have been obliterated. On the other hand, if we cross over to Central France, we find in the region of Mont Dore ancient craters in a remarkable state of preservation, and which were, apparently, contemporaneous with those of the north of Ireland. To the same period are also referable (in all probability) some of the volcanic cones of Germany, Hungary, Transylvania; and it is unquestionable that the Miocene period was one of extraordinary volcanic activity over large European areas, in which the original outline of the centres of eruption have been more or less preserved. With us, however, it is different, and it is plain that the north of Ireland and the western isles of Scotland have been subjected to agents of abrasion from which the other districts I have referred to have been to a great extent free.

It is to the various agents which were in operation chiefly during the Glacial epoch that we must, as it seems to me, refer the obliteration of the volcanic craters of the north of Ireland. These agents, indeed, were sufficiently numerous to exercise a most powerful effect in denuding the surface of the country. For, to the ordinary action of rain and rivers, must be added at one time the planing of an ice-sheet, and at another the levelling of the waves of the sea. The glaciated surfaces of the basaltic rocks at Fair Head and numerous other places attest the former presence of the one; while the beds of marine gravel, occurring especially in the adjoining district of Armagh, up to elevations of 200 or 300 feet, indicate the former presence of the other.

The amount of denudation in the north of Ireland since the period of the Miocene volcanos has indeed been enormous. Hundreds of vertical feet of basaltic rocks have been removed, considerable valleys, like those of Belfast Lough, Cushendall, and Bushmills, have been scooped out, and considerable tracts surrounding the

basaltic region have been stripped of their former covering of trap.

Since the close of the Miocene period no volcanic outbursts have taken place over the area of the British Isles. The fires of that remarkable epoch have spent themselves here, and have retreated to Iceland on the one hand, and the borders of the Mediterranean on the other. Happily for us, we are not called on to witness the entombment of a Pompeii, or the destruction by a fiery torrent of a Catania. If these phenomena are to be witnessed, it must be at a distance from our own more fortunate Isles.

VI.—NOTE ON A SMALL RAISED ESTUARINE BEACH AT TRAMORE BAY, CO. WATERFORD, SHOWING TRACES OF SEVERAL OSCILLATORY MOVEMENTS DURING THE RECENT PERIOD. By EDWARD T. HARDMAN, F.R.G.S.I., F.C.S.; of the Geological Survey of Ireland, Associate of the Royal College of Science, Dublin.

[Read December 10, 1873.]

WHILE spending a few days in the Autumn at Tramore, I chanced to meet with a well-marked example of recent alteration of shore-level; and as on subsequent examination I find it only partially noticed on the Six-inch Map, and not referred to at all on the published One-inch Sheet, or in the Memoir of the Geological Survey of the District, I thought of laying a short note on the subject before this Society.

The Bay of Tramore is separated by a long ridge of sand-hills known as the Burrow—chiefly of aerial origin—from an extensive muddy estuarine flat called the Backstrand, the result of the silt of two or three streams flowing into and through it, at present of trifling size, but which must formerly have been of some importance as mud-carriers, as is shown by the dimensions of the old river-courses now filled by alluvium. These streams coalesce into one, that finds its way to the sea by a narrow passage called the Rinnashark. At various places around the estuary, and at heights varying from two to ten feet above high-water mark, layers of sand, clay, and gravel are found, resting on Boulder-clay, vegetable soil, or—as in one place—a thick layer of good peat bog; and containing numerous specimens of recent marine shells, chiefly the common cockle,—*Cardium edule*,—with *Turritella*, *Littorina*, *Modiola*, etc. Time did not permit of my making a very careful examination of the fossil contents of these beds. I was, however, able to trace the Raised Beach for about a mile on each side of the estuary. On the east side it is very well marked indeed as to configuration, forming a narrow stretch of low flat ground along the margin of the shore, and with shells tolerably abundant, these being also found at some little distance from the shore, in the sides of a ditch a field off. But on the west only a few isolated patches of shelly gravel were to be found; and the shape of the shore is not such as to suggest the existence of a raised beach. Yet of this there can be no question, as will be seen from the following details.

The first section seen on the west, at the north-eastern junction of Crobally Upper with Crobally Lower, and near the former mouth of one of the streams flowing into the bay, is as follows :

(See Illustration, Fig. 1, p. 34.)						Ft.	In.	Ft.	In.
c.	Mould, clay, etc. (artificial)	...	...	...	...	2	0		
b.	Stratified sand containing fragments and whole shells of <i>Cardium edule</i> , <i>Turritella</i> , etc...	...	...	...	...	2	0	10	0
a.	Boulder-clay, with Talus of recent sand, etc., in all	...	...	...	...	8	0		

The shelly bed here is somewhat variable in thickness—from six inches to two feet—and in level; but its height above present high-water mark is about ten feet.

Crossing the stream, and proceeding northwards along the coast for about 600 yards, we come to a place marked on the working Six-inch Map with the following note by Mr. W. L. Willson, who examined this district in the early days of the Survey:—"Layers of Cockle-shells (*in situ*) $2\frac{1}{2}$ feet above present level of high-water, imbedded whole as if buried alive, in clayey drift." I could not find the deposit here alluded to, as it has been "improved off the face of the earth"; but a little to the east of the spot, in a new drain running from a sluice gate in the recently built Reclamation Wall, crossing the estuary from this point, I saw the following remarkable section (see Illustration, Fig. 2, p. 34):—

						Ft.	In.
e.	Clayey bed with broken Cockle-shells, about	...	...	...	...	0	8
d.	Brown solid Peat	...	...	...	...	2	0
c.	Clayey brown Sand	...	...	...	...	2	0
a. b.	Brown clayey Boulder-clay, with cracks or pipes filled with blue stiff clay, to water's edge...	...	...	...	...	1	0
						5	8

The Cockle-bed was at a height of from two to three feet above high-water mark: Had I not seen other sections having a direct bearing on the above, and of some if not entire similarity to it, I should have been inclined to reject bed *e* as of artificial origin: but, as the sequel will show, there is a strong presumption that it is really *in situ*. In a drain along a new road, being the continuation of the wall to the westward, a somewhat similar section is seen :

(See Illustration, Fig. 3, p. 34.)						Ft.	In.
d.	Soil, etc.	...	...	...	...	1	6
c.	Peaty layer, becoming sandy inland	...	...	...	...	1	0
b.	Bluish mud containing fragments of wood...	...	...	...	...	1	6
a.	Sandy Boulder-clay, with cracks filled up with blue mud...	...	...	...	...	4	0
						8	0

The shells are absent here, possibly because the former submergence did not extend so far. The peaty layer undoubtedly corresponds with the boggy bed of the last section.

Five hundred yards north of the sluice-gate, and close to the division of the Townlands, Ballinatin, and Drumeannon, Mr. Willson has noted "Layers of Cockle-shells $2\frac{1}{2}$ feet above high-water mark." This has also disappeared.

The foregoing are the only traces to be found on the west of the

estuary; but on crossing the Reclamation Dyke to the other side, the old beach becomes very apparent, and a little to the north, about sixty yards from high-water mark, an excellent section is seen (See Illustration, Fig. 4, p. 34):

Section in Lissellan.

	Ft.	In.	Ft.	In.
d. Vegetable soil and clay	1	0		
c. Dark sandy layer, rather peaty, containing abundantly at base layers of shells, Cockle, Mussel, Winkle, etc.	0	3 to 0	6	
b. Muddy layer, thin and irregular, in pockets	0	2		
a. Gravely brown Boulder-clay with irregular cracks containing blue mud strings	6	0 to 9	0	
	7	5 to 9	6	

The height of the shell-bed is here about nine or ten feet above high-water mark, and it is found extending inland in a section exposed in a ditch, continuing into the next field.

A little south of this, and close to high-water mark, the same section is seen; but here bed c. becomes very black, from the presence of organic matter, in some places very peaty, and thickens to one foot. Bed b. is sometimes a foot thick, and the height of the shell-bed is seven feet above high-water mark.

Continuing southwards in Lissellan, the peaty layer is underlaid by a few thin layers of well-stratified gravel, full of shells, which die out after a little distance. Further on along the shore the level of the peaty bed sinks gradually, and at last is covered by a distinct layer of rudely-stratified gravel, in which a few shells are found, being evidently a shore deposit. This, which is about a foot thick, and is covered with mould well clothed with grass, continues for nearly half a mile, the height diminishing to about two feet, until it gradually disappears under a thin bog connected with an alluvial flat. (See Illustration, Fig. 5, p. 34.) This bog is itself covered by high-water of spring-tides.

I think there is sufficient resemblance between these sections and Figs. 2 and 3, to warrant us in referring them all to one horizon, and in believing the shells above the peat in Fig. 2 to be *in situ*, corresponding to the gravel-bed above the black bed in Lissellan.

North of the Wall (or of Section 4) the raised beach can be traced for about half a mile by its appearance, which is tolerably distinct. It seems to die out towards the head of the estuary.

Although this beach is of insignificant extent, it is of some interest on account of its recording several oscillations of surface as having occurred during Post-Glacial times; for it will be observed that from the sections three distinct land-surfaces and as many silt-beds can be identified. First and lowest comes the Boulder-clay, evidently denuded, perhaps after depression, and a deposit of mud and gravel, with shells laid on it—First Submergence. Then we have the land rising again, marked by a dark sandy bed full of vegetable matter (? old alluvium), with, in places, shells at the base, becoming in part peat bog—Second Land-Surface. Next comes a deposit of gravel, stratified, and in at least two places containing shells—Second Submergence. This is covered by quite recent bog passing

RAISED BEACH AT TRAMORE.

VERTICAL SECTIONS.

FIG. 1.

FIG. 2.

FIG. 3.

FIG. 4.



The numbers 1, 2, 3, . . . are intended to show the correlation of the different beds.

FIG. 5. SECTION ALONG SHORE AT LISSELLAN.



SCALE.—*Longitudinal*: 12 in. = one mile. *Vertical*: 1 in. = 36 feet.

7. High-water of Spring-tides, covering Bog, and probably leaving a sandy deposit..... 3rd Depression commencing (?).
6. Bog, passing in parts into Alluvium 3rd Land Surface.
5. Upper Gravel bed, with a few shells 2nd Depression.
4. Dark Peaty sandy layer. Shells abundant at base 2nd Land Surface. Land Rising.
3. Lower Gravel Bed; Curved Stratification. Shells very abundant. } 1st Depression.
2. Blue mud layer, extending into cracks in (1) 1st Land Surface.
1. Gravely Brown Boulder-clay, eroded

To illustrate Mr. E. T. Hardman's paper.

into alluvium along the Keiloge River—Third Land-Surface. And the last is now subject to floods at spring-tides—showing that the Third Submergence has commenced.

With regard to this last, it may be mentioned that at the south-western corner of the estuary, close to the town, there is a partially-submerged and silt-covered bog,* which appears to be connected with an alluvial flat extending northwards. This bog has been buried for many years, for it was recorded on the Six-inch Working Map by Mr. Willson in the beginning of the Survey. At present there is no trace of it; but during the great storm of 1870 the strand was torn up and the bog laid bare. In the summer of that year I happened to be in the neighbourhood, and visiting the strand saw the bog where it was even then visible between high- and low-water mark. It appeared to have been covered by not more than six inches of sand, and was certainly *in situ*, and not the result of a quantity of bog having slipped, and spread over the sand. Had this been so, it must have been levelled and removed by the tidal action long before I saw it. The strand being now re-formed, there is none of the bog visible. It is possible that it is contemporaneous with the alluvial bog referred to above as capping the last gravel-bed in Section 5, at Lissellan; but that either because the land commenced to sink towards the south, or by reason of the slope of the ground, the latter has as yet only barely come within the influence of the water.

The subject of changes of level in estuaries as shown by the presence of alternating beds of peat or vegetable soil and silt, etc., has been well treated by Mr. T. Mellard Reade, F.G.S., in an elaborate and exhaustive paper on the Estuaries of the Mersey, Dee, and Ribble,† in which he has made out from three to four distinct periods of submergence and upheaval, and he insists on the frequency of such movements. This idea seems to me to be well borne out by the number of sea and land surfaces shown in such a trifling thickness of strata as at Tramore. At the same time, we must remember that extensive denudation might have taken place between each deposit, although this is not denoted by what is going on there at present, since we see one part of the bog submerged and silted over, while the other is still growing.

With regard to other parts of our own coasts, I have no doubt that the same phenomena have been also observed; but I have no opportunity of verifying this at present. However, the shelly gravel of Dundalk‡ may possibly be due to something of the same nature, and this is undoubtedly true in the case of the remarkable shell and

* The strand under which it lies is covered totally at high-water.

† Post-glacial Geology of Lancashire and Cheshire, by T. Mellard Reade, C.E., F.G.S., etc., Proc. Liverpool Geol. Soc., November, 1871. An instance of blue mud penetrating into cracks in the Boulder-clay beneath is noted (p. 46, Detailed Sections), just as in the Sections given above. (See GEOL. MAG. 1872, Vol. IX. p. 111.)

‡ On the Shelly Gravel underlying Dundalk, by Gen. Portlock, F.R.S., etc., Journ. Dub. Geol. Soc. Vol. I.

peat deposit underlying Belfast:* while another instance in the South of Ireland is furnished by the Estuary of Wexford, of which, through the kindness of G. H. Kinahan, Esq., M.R.I.A., I am in possession of some details showing that recent oscillations have been going on there to a great extent. Around the coast, submerged bog is common, and in the Estuary itself the following section is noted by him:†—

“North Mudlands, Wexford Estuary, at the Engine House at the ancient island called ‘The Ridge.’

									Ft.	In.
4.	Marl	...	...	...	...	...	...	...	16	0
3.	Peat	...	...	...	...	...	...	...	5	0
2.	Grey muddy stuff	...	...	...	...	...	...	...	1	5
1.	Marl	...	...	...	...	...	...	...

“The top of the marl, No. 4, is a few fathoms (about four) below average high-water mark. This section was procured while sinking the foundation of the Engine House.”

VII.—THE ELEVATED SHELL-BEARING GRAVELS NEAR DUBLIN. By
Rev. MAXWELL CLOSE, M.A., F.G.S.

[Read 8th January, 1873.]

THE elevated Drift deposits near Dublin have been brought under the notice of the Society by other observers. The late Mr. John Kelly has described in our Journal (Vol. VI. p. 133) part of the gravels which form the subject of this paper; including the collection at Caldbeck Castle, 1300 feet above the sea. I have already mentioned before the Society (in 1867) the fact of having found marine shells in the Pleistocene gravels near Dublin, at heights of 1000 and 1200 feet above the present sea-level;‡ but I did not wish to offer a paper on the subject until I had collected what might seem sufficient materials for one. These shells are not only in a very fragmentary condition, but also scarce, so that they easily escape notice; and it is necessary to pay several visits, at sufficient intervals, to the few places where the shells are accessible, in order to obtain from thence even a limited collection of determinable species.

The gravels now in question belong to the “limestone gravel” of Ireland, and occur on the sides, or in the immediate vicinity, of the hill mass, the best known of whose prominences is named the Three-Rock Mountain—part of the N.E. end of the Wexford, Wicklow, and Dublin granite range. Ballyedmonduff is on the S.E. side thereof, on the road leading from Stepaside to Glencullen. A little

* Mr. J. Grainger, 22nd Report Brit. Assoc., 1852, p. 42. Also Ex. pl. Memoir (Sheet 36), Geol. Survey, Ireland, p. 38.

† MS. note.

‡ These are noticed in Jukes’s “Manual of Geology, edited by Prof. Geikie; by Prof. Harkness in the GEOLOGICAL MAGAZINE, Vol. VI. p. 546; and in Sir C. Lyell’s “Student’s Elements of Geology,” where, however, they are placed in the Co. Wexford, and in the Pliocene formation.

below, and N. of, the highest point of that road, on the E. side of the road, just opposite Ballyedmonduff House, and at the elevation of just 1000 feet, is a gravel-pit which has yielded the shells given below. The distinctly-shaped mound, or mamelon, in which the pit is dug, is chiefly composed of clean stratified gravel and sand; it is part of a great collection of Drift which extends into the S.E., or Ballyedmonduff, bosom of the above-mentioned hill mass, and over the slight *col* at the highest point of the road leading to Glencullen; at which latter place it (the gravel) is of very considerable depth. In the said bosom the gravel maintains, at its upper edge, an elevation of about 1100 feet, for some distance; and spreads thinly over the hill-spur, marked on the map 1103 feet.

Shells at Ballyedmonduff, 1000 feet.—*Trophon muricatus* C, *Fusus*? (part of columella), *Turritella communis* CN, *Ostrea edulis* C, *Pecten* (two species), *Cardium edule*, *C. echinatum*, *Astarte compressa* CN, *A. elliptica* CN, *A. sulcata* CN, *Cyprina Islandica* CN, *Artemis linctata* CN, *Venus striatula*, *V. casina* C, *Lutraria elliptica*, *Mactra stultorum*?, *Tellina*?, *Mya truncata*? CN, *Pholas crispata* C, *Balanus balanoides* CN, *Small shell-boring Annelid* (perforations of).

The species, as also those named below, were determined by Mr. W. H. Baily and Dr. Carte. Those marked C are characteristic of the Celtic province of marine fauna (*Venus casina* is thus marked, although occurring exceptionally in the Mediterranean; as Edward Forbes believed it must have attained access thereto during the Glacial submergence). Those distinguished with CN are characteristic of Celtic and Northern European seas; or of the northern part of the Celtic area.

The remains of the house called Caldbeck Castle stand westward of the Three Rocks, on the *col* above Ticknock, which connects Kilmashogue Mountain with the rest of the said hill mass. About one furlong S. of the ruins is a pit, in clean gravel and sand, at the elevation of a little over 1,200 feet (slightly higher than the shell-bearing gravels near Macclesfield, described by Mr. R. D. Darbishire, F.G.S., * *Memoirs of Lit. and Phil. Soc. Manchester*, vol. iii. 1868), which has yielded the following species.

Shells near Caldbeck Castle, 1200 feet.—*Fusus*? (part of columella), *Cardium echinatum*, *Cyprina Islandica* CN, *Venus striatula*, *V. casina*? C, *Mactra stultorum*, *Small shell-boring Annelid* (perforations of).

A little below, towards the S.W., in the bosom between the Kilmashogue and Tibbradden hill spurs, *Cyprina Islandica* and other shell fragments can be found near the stream, at just 1000 feet. In the Killakee valley running up between Tibbradden Hill and Killakee there is an immense irregular accumulation of Drift. In two gravel-pits near the wood where the Ballybrack road enters that valley, and at the height of 850 feet, were found, among other shell fragments, portions of *Cyprina Islandica* and *Cardium echinatum*. And near the head of that valley, beside the road, among some trees,

* See *Geol. Mag.* 1865, Vol. II. p. 293, with table of shells.

and not far from where the military road passes, at the height of just 1200 feet, there is a pit which yielded a few fragments, of which only *Cyprina Islandica* and *Astarte elliptica* are recognizable. And finally, a little below, and S.E. of, the summit of Montpelier Hill, at the elevation of a little over 1200 feet, there is a long-disused and much grass-grown gravel-pit, in which one indeterminate shell fragment was found. This pit is four and a half miles from that first mentioned.

It is to be observed that, though all the above individual species live now in the neighbouring seas, yet, as a group, they present a rather more boreal *facies* than those of the present coasts, and than those of the low gravels, as a group (see paper by Prof. Oldham, Journ. Geol. Soc. Dublin, Vol. III. p. 131), and a decidedly less northern *facies* than the much larger collection of Drift shells from Moel Tryfaen, at 1360 feet elevation. However, it would be scarcely prudent to found any argument on the limited induction that we have been able to make. Two other points seem worthy of notice, though they may be but accidental: viz. that of *Cardium edule*, which occurs so frequently in the gravels at lower elevations, near Dublin, only one fragment has yet been recognized in the higher accumulations; and also, that but three univalves have been found, although shells of that class must be generally better able, than others, to withstand rough usage, and therefore more capable of handing down determinable fragments. Pieces of *Cyprina Islandica* are the most common, evidently on account of the thickness and strength of that shell.

What then is indicated by the occurrence of marine Drift shells in those elevated situations in our neighbourhood? Not as much as might, perhaps, be supposed on first thoughts. We did not need their presence to assure us that the sorting and stratification of those elevated gravels and sands was effected by the sea; for, as Mr. Kelly has pointed out in his paper, it is utterly impossible to refer that to any other agent. And, moreover, those shells do not give us any information as to the character of the marine fauna of this district when the sea covered it so deeply. The gravel, etc., in which they occur is "limestone gravel" (with a slight sprinkling of granite stones), resting on granite hills; this has been carried thither from elsewhere; and the smashed condition of the shells, and the fact that those fragments, which are large enough to show it, are often well scratched, like many of the pebbles among which they lie, lead to the conclusion that those fragments form, as it were, part of the gravel and have been carried thither along with it, and that, therefore, the animals did not live and die where their remains are now found. (It would seem from the descriptions, especially by Mr. D. Mackintosh, F.G.S., of the Moel Tryfaen gravels and shells, that the same has been the case with the Drift shells of that place.) This conclusion is strengthened by the consideration that, when the sea was up at the level of the site of Caldbeck Castle, the ground would fall steeply down from the very shore-line in all directions to a great depth; and several at least of the above shells

would be without sufficient platform, or suitable habitat, for their subsistence.

But how were the limestone gravels and the shells carried to their present positions on the granite hills? Let us note that only a very small proportion of the gravel stones exhibit signs of water-rolling; they are generally subangular; many are greatly scratched (these occur more usually in the upper parts of the gravel), and some are quite angular. Again, at Caldbeck Castle, the nearest part of the limestone ground is $2\frac{3}{4}$ miles distant, and 900 feet lower down; and at Ballyedmonduff pit the nearest part is $4\frac{1}{2}$ miles distant, and 800 feet lower down; yet the proportion of limestone and other foreign pebbles, etc., in the gravel at those places is at least 99 per cent. It seems utterly impossible that that gravel could have been swept thither by water, along the surface of the ground, for at least those distances, and up-hill too, without having its pebbles nearly all rounded, and without picking up vastly more than one per cent. of granite stones. Again, at Ballyedmonduff pit there is, in one part of the large irregular excavation, and in the upper part of the section, a mass of earthy clay packed with blocks of limestone and grit, some as large as a man's head, and all greatly scratched; this looks almost exactly like true Boulder-clay (it probably belongs to the Upper Boulder-clay), and it overlies fine gravel and sand (all this is now much obscured by some trees having fallen and torn down the pit escarpment). Any rush of water that could have carried those stones along bodily, without rolling them, could not have deposited the fine materials on which they lie, and must have swept away those fine materials, if they had been already there. Since rushing water is out of the question, as the transporting agent, and also, as will be generally conceded, land-ice, for somewhat similar reasons, we seem compelled to believe, as Mr. Kelly did, that the gravels in question have been transported by floating-ice to their present situations (apparently from a north-westerly direction). The blocks of local granite, weighing sometimes up to 20 tons, which usually lie on the top of the (limestone) gravel, in places to which they could not have fallen or rolled, must have been left there by floating-ice; but this may have been local and more immediately connected with the hills.

The upper limits of these gravels are clearly not raised beaches. Yet on the south-east side of the Three-Rock Mountain, in the Ballyedmonduff bosom, there is an approach to a horizontal upper boundary, at the height of about 1100 feet, extending for about a mile; and about Caldbeck Castle and the head of Killakee valley, on the other side of the hill mass, a less near approach to such a boundary, at 1200 to 1300 feet, extending for two or three miles. Of course the upper limit of the gravel, as worthy the title of a deposit, does not necessarily indicate the greatest depth of the submergence in the glacial sea. Above that limit many pieces of foreign material can be found, almost to the summit of the Two-Rock Mountain, at the height of about 1760 feet.

As to the correlation of these high-level gravels with those on the

low grounds—it seems impossible, at present, to ascertain their *precise* relations, from direct observation. Speaking roughly, they both evidently belong to the same formation, viz. the Pleistocene “middle sands and gravels,” lying below the Upper, and above the true or Lower Boulder-clay. But, considering the most probable mode of transport, and the fact that the submergence of the low grounds must have begun sooner and ended later than that of the high grounds, we may perhaps conclude more definitely that the elevated gravels are contemporaneous with some of the middle parts of the low gravels.

Recapitulation (in different order).—1. The elevated gravels are Pleistocene, and probably contemporaneous with some of the middle parts of the low-level gravels. 2. They have been carried to their present position by floating-ice. 3. The contained marine shells have been brought along with the gravel. 4. Therefore the animals to which the shells belonged lived and died somewhere else, towards the northwest, and *that* very possibly before the time when the sea was deep enough to deposit the elevated gravels. 5. The shells, as a group, if we may venture to judge from so small a collection, point to rather more boreal marine conditions than now obtain in this region; although they are all to be found now inhabiting the neighbouring seas.

VIII.—REMARKS ON THE PALÆOZOIC *ECHINIDÆ*, *PALÆCHINUS*, AND *ARCHÆOCIDARIS*. By WILLIAM HELLIER BAILY, M.R.I.A., etc.

[Read 8th April, 1874.]

ON two previous occasions, March 9th, 1864, and April 12th, 1865, I communicated to this Society some new facts I had discovered, in relation to the structure of *Palæchinus*.

I propose now to supplement the remarks on that genus, and of *Archæocidaris*, with some additional notes on these Palæozoic Echinidæ.

In the “Synopsis of the Carboniferous Fossils of Ireland,” published by Sir Richard Griffith, Bart., Professor McCoy enumerates five species of *Palæchinus*, namely, *P. elegans*, McCoy; *P. ellipticus*, Scouler, MS.; *P. gigas*, McCoy; *P. (?) Konigii*, McCoy; and *P. sphaericus*, Scouler, MS. Figures being given of all these species.

Palæchinus Konigii is described from a single central plate only, the others, with the exception of *P. gigas*, are from nearly entire specimens.

In one of the communications I have alluded to, I described and figured the apical disk, spines, and perforated tubercles in *Palæchinus elegans*, one of the most abundant species in the Lower Carboniferous Limestone of Hook Head, parts not before noticed in any of the species.

Four years after the publication of this discovery, Professor De Koninck described and figured in the “Bulletins de l’Académie Royale, Belgique,” series 2, tome xxviii. pp. 57–65 (1869), a speci-

men of *Palæchinus sphericus*, from the collection of Mr. Edward Wood, of Richmond, Yorkshire, found in the Carboniferous Limestone of Kirkby-Stephen, Westmoreland. This he states to be "remarkable, on account of the presence of the apical plates, which are well preserved, and which have not yet been seen in any other specimen of the same genus." The figure he gives shows only the five genital plates. Four of them he describes as "identical, each being perforated by three rounded and well-marked pores. The fifth plate differs in form from the other four, and has only a single pore placed nearer the border of the anal aperture." He observes also that "the specimens examined by him do not show any trace of ocellar plates."

The priority of my discovery of the apical disk of *Palæchinus elegans* several years before was evidently unknown to Professor De Koninck, our fossils showing, in addition to the five genital, four of which are perforated by three pores each, as in the specimen described by him; five ocular plates, each with a double perforation, and two inner circles of sur-anal plates.

The fine typical specimen, *Palæchinus gigas*, McCoy, in Sir Richard Griffith's collection, from Lower Carboniferous Limestone Shale, Raheen, Co. Donegal, is a portion of the test of this large species, showing part of one of the ambulacral areas, with its numerous plates, to which is attached three imperfect rows of inter-ambulacral plates composed of seven, six, and five plates each, nearly half an inch broad (Plate III. *a.*). Doubled over on the reverse side of this fossil are two other rows of similar inter-ambulacral plates, six and seven in number (Plate III. *b.*), which appear to have been originally attached to the opposite margin of the same ambulacral area, the adjoining plates on both sides of the ambulacra being pentagonal, and the intermediate rows hexagonal.

It is from this specimen Professor McCoy has given the restored figure in the Synopsis (Carboniferous Fossils of Ireland, plate xxiv. fig. 4). Although there is no actual foundation for as many as six rows of inter-ambulacral plates, it is possible he may have been correct in the supposition that it possessed the same number as in *Palæchinus sphericus*.

Having had an opportunity, through the kindness of Sir Richard Griffith, of making a careful drawing and minute examination of this specimen (Plate III. *a.-d.*), I am enabled to show some points of its structure which have been omitted in the published description, and others incorrectly represented. In the plate before referred to (Synopsis Carboniferous Fossils) the enlarged outline, fig. 4 *c*, is entirely incorrect. The number of ambulacral plates to each inter-ambulacral plate is shown on this figure to be only six, whereas there are about 13, at least twice the number. Each of these ambulacral plates is covered by a row of five or six *perforated* tubercles, surrounded by eight or ten smaller tubercles. These perforations, and the surrounding tubercles, are not shown at all in the enlarged figure of an hexagonal plate (*b.*), the tubercles being represented imperforate, surrounded by a continuous ridge,

and of too large a size in proportion to that of the plate, which is also incorrect in shape.

Each of the ambulacral plates is perforated by a pair of pores only. In figure *c*, before referred to, two pairs are represented. This is clearly an error. The arrangement, a remarkable one, is the following. Every alternate plate being expanded at its junction with that of the inter-ambulacra, the intermediate ones are consequently shorter; nevertheless each bears a pair of pores, which are so arranged as to form a zigzag series, as shown on the enlarged outline of a portion of the ambulacra, with its connected inter-ambulacral plate (Plate III. *c*).

The inter-ambulacral plates are covered by about 14 rows of perforated tubercles, similar to those of the ambulacra, surrounded by 8 or 10 smaller ones (Plate III. *d*).

Of the genus *Archæocidaris*, McCoy, 1840 (*Cidaris*, Phillips, 1836), six species are enumerated from British strata, five of them from Carboniferous and one from the Permian. As these species are all defined from detached plates and spines only, they are in consequence scarcely satisfactory.

These detached plates of *Archæocidaris*, from their six-sided form, were also like the *Palæchinus*, evidently arranged in more than a double series. They have usually one large perforated tubercle surrounded by a strong circular ridge, and corresponding depression. Beyond this is a slightly raised ridge, also surrounding the tubercle, from which radiate raised striæ and granulations.

The spines are about two inches long, perforated at the base for the attachment of the ligament, and covered by longitudinal rows of irregularly arranged murications.

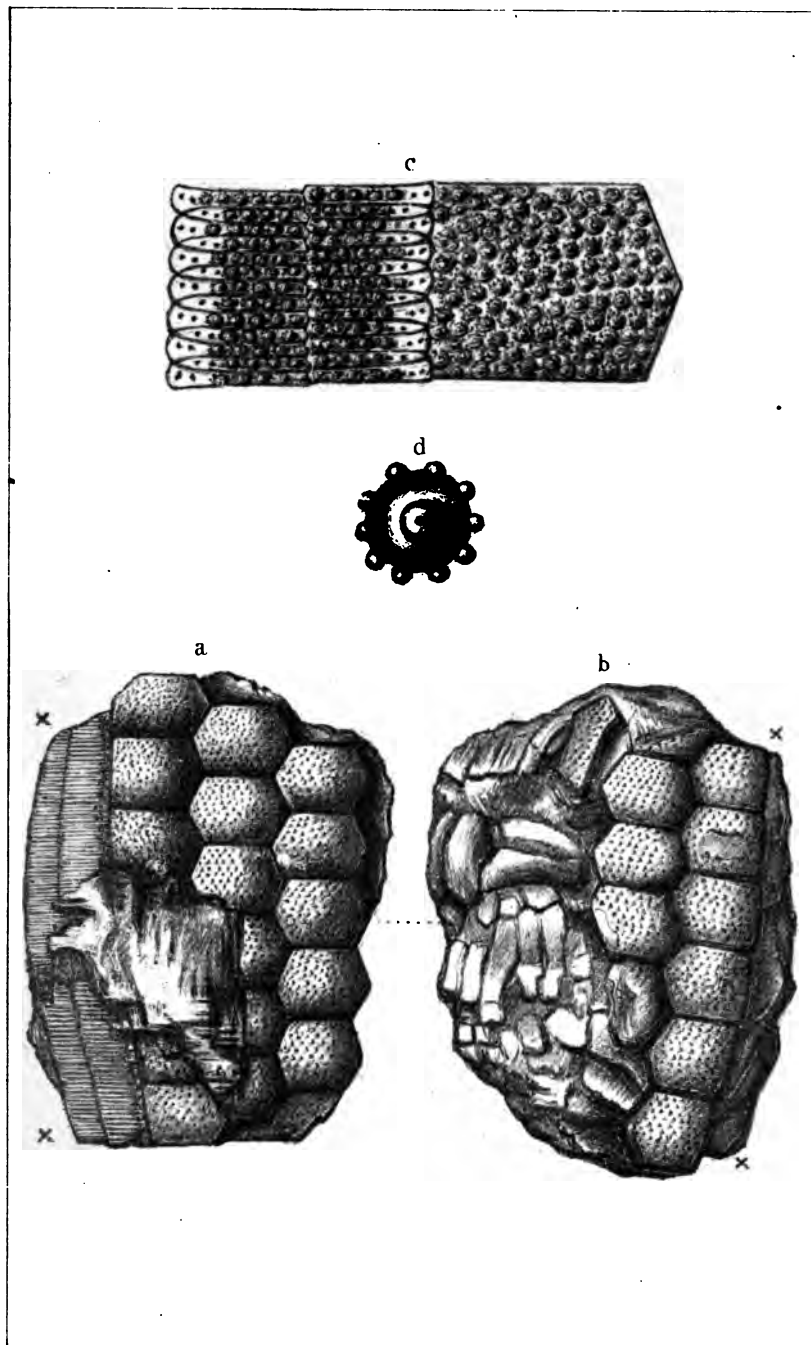
The very interesting fossil discovered by Mr. William Harte, C.E., County Surveyor of Donegal, and partially described as a new *Echinoderm*, but not named, in a paper read before this Society April 13th, 1864,* may I consider be (provisionally, at least) included in the genus *Archæocidaris*, to which it is more closely related than to *Palæchinus*. This specimen, liberally presented by Mr. Harte to the Museum of Trinity College, I have, through the kindness of the Rev. Dr. Haughton, re-examined.

It is a cast or impression in calcareous grit, belonging to the Lower Carboniferous formation, and is the only example known of *Archæocidaris*, in which the parts retain their original form and connexion with each other. The alternation of tubercled and non-tubercled plates are characters not before noticed in *Archæocidaris*, perhaps because the plates have never hitherto been found connected; and when detached from each other, those without tubercles are very likely to be mistaken for plates of *Palæchinus*.

I propose to name this fine and well-preserved fossil, in honour of its discoverer, *Archæocidaris Harteiana* (Plate IV.).

The test or shell is subglobose, $2\frac{3}{4}$ inches in diameter.

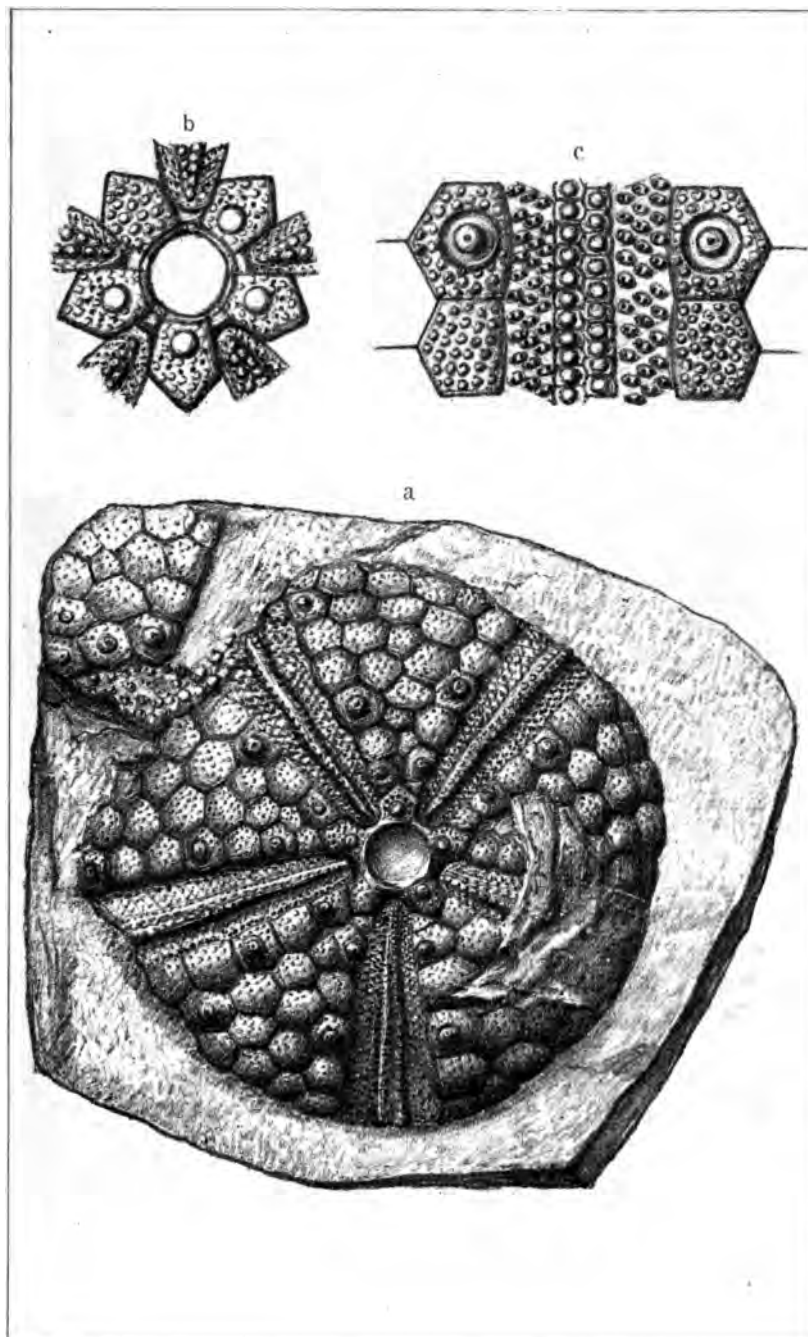
* Journal Royal Geological Society of Ireland, Vol. XI. p. 67.



W. B. Hosley, del. ex lith.

Forster & Co. Dublin

PALÆCHINUS GIGAS (McCoy)



W. B. Baily, del. ex lith.

Forster & Co. Dublin.

ARCHÆOCIDARIS HARTEIANA (*Baily*)

The apical disk (shown enlarged, Plate IV. *b.*) is composed of the usual number of five genital plates (cinquefoil in shape). Four of these plates bear a large tubercle, round which, in a semi-circle, are six perforations (not 16, as Mr. Harte describes). The madreporiform plate is apparently covered by granulations only. The ocular plates were small, and are too obscure for description.

The ambulacral areas are sinuous, the plates composing it are in the proportion of about six to one of the largest inter-ambulacral plates. Each plate bears one perforated tubercle, forming a central ridge on each side of the median line. The poriferous openings occupy a wider space, and are arranged in diagonal rows of three oblong circles bearing a pair of pores each.

The inter-ambulacral areas are composed at the widest part of five rows of irregularly arranged pentagonal and hexagonal plates. The number of rows decreases towards the apical disk, until they are reduced to two small plates only. Every alternate plate on the rows next the ambulacra bears a large perforated tubercle, surrounded by a circular ridge and depression, as in *A. Urii*. Much smaller tubercles or granules cover the remainder of the plate, as they do also the alternate and intermediate ones. An enlarged representation of a portion of the ambulacra and adjoining inter-ambulacral plates is shown on Plate IV. *c.*

Geological Formation.—LOWER CARBONIFEROUS, Calcareous Grit.

Locality.—Western shore of Lough Eske, about six miles from Donegal.

EXPLANATION OF PLATES.

PLATE III.—*a-d.* *PALÆCHINUS GIGAS*, *McCoy*.

- a.* Group of portions of three rows of inter-ambulacral plates, connected with a large part of one of the ambulacra. Natural size.
- b.* Opposite side of the same specimen, showing portions of two rows of inter-ambulacral plates, originally connected with the same ambulacra (at *x x*), but now doubled over. Natural size.
- c.* Portion of ambulacra and connected inter-ambulacral plate. Enlarged three diameters.
- d.* One of the tubercles, with surrounding smaller tubercles (much enlarged).

LOWER CARBONIFEROUS (Limestone Shale), Raheen, Co. Donegal.

„ IV.—*a, b, c.* *ARCHÆOCIDARIS HARTEIANA*, *Baily*.

- a.* Genital surface, from a cast in plaster of Paris taken from the original mould. Natural size.
- b.* Apical or genital disk. Enlarged to twice natural size.
- c.* Part of ambulacra and connecting inter-ambulacral plates. Twice natural size.

LOWER CARBONIFEROUS (Calcareous Grit), Western shore of Lough Eske, near Donegal.

IX.—ON THE MICROSCOPIC STRUCTURE OF THE LAMBAY PORPHYRY
(OR PORPHYRITE). By PROFESSOR EDWARD HULL, M.A., F.R.S.,
President R. G. S. I.

[Read 13th April, 1874.]

THIS very handsome rock forms almost the whole surface of the Island of Lambay and of the adjoining coast, a few miles to the north of Dublin Bay. It is also laid open in the railway cutting at Donabate Station; and has received considerable notice owing to its intrinsic beauty as an ornamental stone, and its proximity to the Irish metropolis. I am informed by Rev. Dr. Haughton that he has identified specimens from the tessellated pavement of St. Kevin's Church, Glendalough, of the seventh century, which were submitted to his inspection by Sir W. Wilde. A polished table, together with a large block presenting two sides cut and polished, are placed in the gallery of the Royal College of Science in St. Stephen's Green; where, to those familiar with the marbles of Italy and Greece, the appearance of these specimens cannot fail to recall the green porphyry (*Marmor Lacedæmonium viride*) so largely used in ancient decorative works of art, and often reset in modern ones, the source of which is in the neighbourhood of Sparta and Marathon.* The two rocks, however, though resembling each other in appearance, are essentially distinct as regards mineral composition, M. Delesse having proved that the Grecian porphyry contains augite as an essential, and is apparently a porphyritic basalt, while the Irish porphyry is altogether destitute of this mineral. As regards geological age, the Lambay porphyry appears to have been intruded amongst the Lower Silurian rocks at a period antecedent to that of the Old Red Sandstone,† as this latter formation overlies the porphyry without appearing to have undergone any alteration along the surface of contact.‡

The appearance of the porphyry is locally variable; but in its normal condition it consists of a dark green base, inclosing numerous pale green crystals of felspar. These crystals are of various sizes up to an inch in length. Occasionally there are cavities inclosing segregations of chalcedony, epidote, chlorite, or calcite, which also fill in little veins and fissures in the rock itself. In some places it is highly vesicular, the cells containing flesh-coloured calcite. The late Professor Jukes and Mr. Du Noyer appear to have considered the rock to be hornblendic—attributing the dark colour of its base to the presence of this mineral; and on the Maps of the Geological Survey it is named and coloured as "Greenstone Porphyry." But the thin translucent slices, one taken from Lambay Island, and the other from

* E. Hull, "Building and Ornamental Stones of Great Britain and Foreign Countries," p. 73.

† Maps of the Geological Survey, Sheet 102, with Explanation by Messrs. Jukes and Du Noyer.

‡ It is represented in a similar manner in Griffith's Geological Map of Ireland. Edit. 1855.

Portrairie, fail under the microscope to reveal this mineral; while, on the other hand, they show that the dark colouring of the base is due to its being highly charged with minute crystalline grains of magnetite, together with which is a little chlorite, imparting the greenish tinge to the rock.

While, therefore, from the character of the rock, it is by no means improbable that hornblende occurs as an accessory in some places, yet on the whole it ought to be regarded as a felstone porphyry; or, to adopt Naumann's term for the quartzless varieties of porphyritic felstones, "*a porphyrite*."* We shall now proceed to consider its microscopic structure in detail, beginning with the base.

The Base.—When a thin slice is examined with a moderate power (magnifying from 24 to 100 diameters), the base is seen to consist of a colourless felsitic material, amorphous, but sometimes containing long minute felspar crystals. Throughout this base small black crystalline grains of magnetite are distributed in immense numbers, often so small as not to come into sight till viewed with a high power. Along with the magnetite, a mineral which I take to be chlorite is abundantly diffused in the form of light green clouds, or else filling up along with calcite cavities and minute fissures. The dense and dark appearance of the base is therefore evidently due to its being charged so fully with magnetite, while the greenish tinge is due to the green structureless mineral which is more or less generally distributed throughout the felsitic base; and which, in all probability, is chlorite.

Orthoclase crystals.—These are abundant, and sometimes well formed. They frequently occur in pairs, sometimes in threes, less frequently in the form of a cross. They vary in size from half an inch downwards. In colour they are pale green, mottled white, and under the microscope are seen to be traversed by cleavage planes and fissures in various directions, altogether different from the fine parallel lines and bands which characterize the triclinic group of felspars. Occasionally, however, a banded structure parallel to the sides of the prism is observable in some of the crystals displayed on the polished block in the Gallery of the College of Science.

Magnetite.—Small black grains of magnetic iron-ore are so abundantly distributed throughout the base as almost to obscure it, unless the slice is exceedingly thin. Along with these are also occasionally larger perfect cubes, showing well-defined angles of 90° as estimated by the eye. It is remarkable, however, that it is only at rare intervals that a crystal of magnetite becomes enveloped in one of the felspar crystals, from which it may be inferred that these latter were consolidated while the iron remained dissolved throughout the materials from which the base was ultimately formed.

Very singular, however, is the manner in which these magnetite grains are arranged around the interior of some small cells, as shown in Fig. 1. Here they assume a stellate, or plumose arrangement,

* B. von Cotta's "Lithology," English Version, pp. 168-9.

branching out from certain centres placed at intervals around the sides of the original cell, now filled in with chlorite and calcite. This structure I regard as due to polarity, the magnetite grains having arranged themselves side by side somewhat in the manner in which steel dust will arrange itself between the opposite poles of a magnet. Dr. Reynolds, however, suggests that the structure is similar to the dendritic form assumed by manganese ore between the laminae of sandstone or shale, and which he has shown to be due to electric force. In this case he supposes the cleavage planes of the calcite to have afforded the necessary conditions.



FIG. 1.—Cell in the porphyry lined with chlorite and filled with calcite. Several stellate prominences formed of minute grains of magnetite project from the walls of the cell into the interior, and are imbedded in calcite. Mag. 25 diams.

Chlorite.—This mineral is abundantly disseminated throughout the base. It also occurs in small irregular grains, or (along with calcite) fills in cracks and cavities in the rock. It is of a pale leek-green colour, structureless, but often inclosing minute cells, probably gas or air bubbles, as shown in Fig. 3. It is to be presumed that this mineral is in every case of secondary origin, and is not directly the product of igneous fusion. It has therefore been introduced by the agency of water, which has permeated the whole mass of the rock through channels inconceivably narrow, and which can only be revealed by the aid of a high microscopic power. In the section of the cavity (Fig. 1) which has been filled in by this material and calcite, the chlorite forms a partial lining, interposed between the walls of the cavity and the calcite which fills the interior, so that it

is probable the chlorite was the first of these minerals infiltrated into the mass of the rock.

FIG. 2.

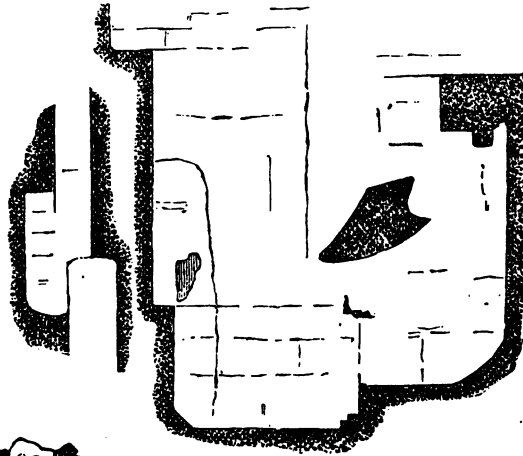


FIG. 3.

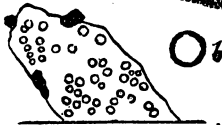


FIG. 2.—Group of orthoclase crystals imbedded in the felspathic matrix, darkened by grains of magnetite. Mag. 25 diams.

FIG. 3.—Cavity filled with chlorite showing cellular structure. Mag. 55 diams.
b. Cell in chlorite. Mag. 400 diams.

Calcite.—The calcite, which is very abundantly diffused throughout the porphyry, occurs chiefly in fissures, often extremely minute, and in the cells, which were probably filled originally with gas or steam. It is always in a crystalline state, and under the microscope the lines corresponding to the cleavage planes of the rhombohedron are clearly developed. With polarized light, the calcite exhibits as usual the faint and delicate pearly or opalescent play of colours, amongst which a pale smalt blue is the most easily recognized.

The calcite is unquestionably due to infiltration; and its abundance may with great probability be attributed to the Carboniferous Limestone of the district, which must once have overspread and covered up the rocks of Lambay and Portraine, which have since been brought to light by the denudation of the limestone. It is easy to conceive that water percolating downwards through the limestone and the thin coating of Old Red Sandstone beneath would become strongly impregnated with carbonate of lime, which it would deposit amongst the fissures and cells of the older rocks beneath.

Along with the minerals here described are also to be found crystals of pyrites; and the order in which the different minerals seem to have been formed is as follows:—First, during consolidation, the crystals of orthoclase; next, the crystalline grains of magnetite;

and lastly the felsitic base itself. Then, after consolidation, chlorite, and calcite, and pyrites.

In fine, it may be said with truth, that but for the aid which the microscopic examination of thin slices of this rock affords, it would have been impossible to have arrived at a correct judgment regarding its mineral composition.

FIG. 4.



FIG. 4.—Portion of polished surface of the porphyry, showing the arrangement of the orthose crystals. Nat. size.

X.—ANNIVERSARY ADDRESS DELIVERED BEFORE THE ROYAL GEOLOGICAL SOCIETY OF IRELAND by the President, Professor EDWARD HULL, M. A., F. R. S., F. G. S., Director of the Geological Survey of Ireland.

[Read February 11, 1875.]

GENTLEMEN,—The recent number of the Transactions of the Royal Geological Society of Ireland bears evidence that the Fellows of the Society have not been backward in geological investigations during the past year. Yet it seems to me, considering the number of Fellows, and the largeness of the field, that more might be done in the way of producing original papers; and with a view towards directing future research, I take this opportunity of pointing out some of those subjects on which further observations seem desirable. Amongst the first, I shall name *Cave Exploration*. On this branch of investigation, which has been pursued with so much zeal and success in England, Belgium, France, and on the shores and isles of the Mediterranean, it is admitted that we in this country are very much behind-hand. The prevalent belief is that the cave fauna of Ireland is very restricted, and that, in consequence of the insular position of the country, and its westerly remoteness from the European centres of distribution, the mammalia of the Post-Tertiary period seldom extended their range to this *Ultima Thule* of the European continent.

This may, or may not, be true; in all probability it is true to a certain extent with regard to many of the extinct quadrupeds of France, Belgium, and England; while, on the other hand, this country is notably rich in the remains of, at least, one noble species of deer—the *Cervus Megaceros*. The existence of the remains of the mammoth (*Elephas primigenius*), and a few other extinct animals, proves that some portion of the Post-Tertiary fauna of the European area did migrate thus far; and it still remains to be determined to what extent this migration took place. For a record of the discoveries hitherto made we are indebted, amongst others, to Professor Harkness, F. R. S.,* and Mr. Robert H. Scott, F. R. S.;† and as their observations are so specially suitable to be embodied in the pages of our Transactions, I reproduce them in brief here for the guidance of future observers.

Professor Harkness mentions three localities where the remains of

* "On the Occurrence of Elephant Remains in Ireland." Geological Magazine, vol. vii., p. 253.

† "Catalogue of the Mammalian Fossils which have been hitherto discovered in Ireland." Ibid., p. 413. Also Appendix to Annual Report for 1864 of the Geological Society of Dublin, February 10, 1864.

the mammoth have been found. The first at Maghery, near Belturbet, on the borders of Monaghan and Cavan, in the year 1715, consisting of four molar teeth, two large, and two small, together with which was a portion of the lower jaw, containing one of the teeth, and a portion of the skull, which fell to pieces on being exhumed.* These remains appear to have been preserved in a small lacustrine deposit.

The second case is that of the rib and other bones of an elephant, discovered in a cave near Whitechurch, six miles from Dungarvan, along with, apparently, the skull and antlers of a reindeer; all of which have unfortunately been destroyed. It is right to observe, however, that the rib referred to was considered by Dr. Oldham to be that of a whale, though elephant remains are probably present in the cave. It is very important that this cave should be further explored.

The third discovery recorded is that which was made in 1859, also in the neighbourhood of Dungarvan, county Waterford.† The locality is Shandon, the remains having been found by workmen when opening a limestone quarry for road material, and which were collected by Mr. Brenan, a resident in Dungarvan. They are now in the museum of the Royal Dublin Society, and have been determined by Dr. Carte as appertaining to the mammoth, cave bear, brown bear, reindeer, horse, and hare, and one as a portion of the humerus of a bird. These remains occur in a breccia, formed of limestone fragments, cemented by carbonate of lime and stalagmite, filling a fissure, which traversed the rock below the surface. The cave and breccia were to some extent explored by Professor Harkness, with the assistance of Professor A. Leith Adams, F. R. S., at that time quartered with the 22nd Regiment in Ireland, but who now holds the position of Professor of Zoology in the Royal College of Science, Dublin, and who, from his experience in cave exploration, is well qualified to carry out the exploration of the Irish caves. The abundance of the remains in the Shandon breccia is evinced by the fact that within the space of little more than a square yard, five elephant's vertebrae, portions of five elephant's ribs and fragments of the metacarpal and metatarsal bones of the reindeer, were found by these explorers. Professor Harkness, from the state of the bones of the mammoth, believes that the animal died on the spot; and, along with the other animals, whose remains were found, took refuge in the cave when death was approaching. Besides the remains of the mammoth, bear, and reindeer, those of the wolf also occur at Shandon. Further explorations in this district are also much to be desired.

¶ The following is the list of extinct mammalia which has been drawn up by Mr. Scott in the paper already referred to. The author also gives details regarding the occurrence of each species:—

* Philosophical Transactions, vol. xxix.

† These are recorded by Sir C. Lyell, "Antiquity of Man," 4th edit., p. 322.

- | | |
|----------------------------------|---|
| 1. <i>Ursus arctos</i> . | 9. <i>Bos frontosus</i> . |
| 2. <i>U. spelæus</i> . | 10. <i>Cervus alces</i> . |
| 3. <i>U. maritimus</i> . | 11. <i>C. elaphus</i> . |
| 4. <i>Canis lupus</i> . | 12. <i>Megaceros Hibernicus</i> . |
| 5. <i>Elephas</i> [primigenius]. | 13. <i>Tarandus rangifer</i> [reindeer].* |
| 6. <i>Hippopotamus</i> . | 14. <i>Ovis. sp. inc.</i> |
| 7. <i>Sus scrofa</i> . | 15. <i>Cetaceans</i> . |
| 8. <i>Bos longifrons</i> . | |

To the above may be added *Ursus ferox*. Part of the skull of *Ursus ferox* (fossilis), obtained from the Lough Erne Canal by the Earl of Enniskillen, is in the museum of the Royal Dublin Society; also of the brown bear (*U. arctos*), obtained by Mr. Gray, at Leinster Bridge, county Kildare. Some of these animals have only disappeared within recent times. Dr. Scouler, in a paper read before this Society in 1836, gives a list of the animals that have disappeared within the period of authentic history, or since the twelfth century, which includes the martin, the wolf, the wolf-dog, the wild boar, the red deer, and several species of birds.†

Another instance of the occurrence of an elephant's tooth, near Carrickfergus, is recorded in the annexed letter from my friend, Dr. Moore, director of the Botanic Gardens, Glasnevin.‡

* See Dr. Carte's paper on "The Remains of the Reindeer which have been found fossil in Ireland." Journ. Geol. Soc., Dublin, vol. x., p. 103. Also by the same Author, on "The Remains of the Polar Bear in Ireland." Ibid., vol. x., p. 116.

† Journ. Geol. Soc., Dublin, vol. i., p. 224.

‡ "Royal Dublin Society Botanic Gardens, Glasnevin,

"January 23, 1876.

"MY DEAR SIR,—In reply to your note having reference to the elephant's tooth found in county Antrim, I have to state that during the year 1837 I had rooms in the Infantry barrack, Belfast, in which to arrange and name the specimens of Natural History. On my staff of assistants I had the eldest son of Patrick Doran, the mineralogist, who collected in the neighbourhood, while I was arranging and naming. He brought me in one day the elephant's tooth in question, which he stated was given to him by a man living near the place, who saw him collecting. The man told him that, about a year previous, he was going up the glen, and saw the tooth sticking out of its side, where the water had washed the drift clay, &c., from it. I gave it to the late General Portlock, who was the officer of the department on which I was employed. I left the Survey in the following year, 1838, and never heard what became of the tooth. The place pointed out to me by Doran, where the man stated to him he found it, was in a deep ravine, leading from a large spinning factory to the left of the old castle at Carrickfergus. This account of the matter will not, I dare say, prove very satisfactory, but it is all I know about it, or that probably ever will be known! General Portlock and Doran are both dead, and I suppose so is the man who found the tooth. It was a very fair specimen, about ten inches long, coloured brown by the debris among which it had lain, but quite clean when rubbed against a rough surface.

"Faithfully yours,

"D. MOORE

"Professor Hull, &c., &c."

Some of the numerous caves which occur at intervals along the Antrim coast, and indicate the limits of the former wave action before the formation of the raised beach, are likely to reward explorers. Three of them, at the Port of Ballintoy, were examined some years ago by Mr. James Bryce* (now Dr. Bryce, of Glasgow), in company with Dr. M'Donnell, and bones were found, which were identified by Dr. Scouler as referrible to those of the horse, ox, deer, sheep, goat(?), badger, otter, water-rat, cod-fish, and several birds. Another cave, on the west side of Carrickarede Island, yielded bones of horse, ox, deer, sheep, dog, cod-fish, skate, and wolf-fish. Dr. Bryce considers that the caves were the abodes of man at the period when the bones were entombed, and that their presence is due to his agency.

In a country like Ireland, so largely formed of limestone rocks, the number of caves and open fissures must necessarily be very great, owing to the percolation of underground streams through the calcareous rocks. Of these the fountains by which the waters of Lough Mask are poured into Lough Corrib, at Cong, are perhaps the finest examples; but others, almost as remarkable, occur in other parts of the country, particularly amongst the limestone hills of Sligo and Fermanagh. Some of these underground watercourses are now dry, owing to changes in the courses of the streams, and they are both numerous, and often ramify far beneath the surface. Occasionally the roof of the cavern, or arch, has given way, and we find deep basins, or troughs, bounded on all sides by solid limestone, along the bottom of which runs a watercourse, emerging at one end, and disappearing at the other. These are to be found all over the district, formed of limestone, between Lough Erne and Sligo Bay; and one of the caves has yielded the tooth of a horse, of which an account was recently given to this Society by Mr. J. Jones, F.G.S., who believes it to have belonged to the *Equus fossilis* of Cuvier. Mr. Jones predicts further rewards for the diligent explorer, grounding his opinion on the analogy of the Belgian caverns, which have yielded such large numbers of mammalian remains to the late Dr. Schmerling, and with which Mr. Jones is himself personally acquainted. But I would observe, that the cave-hyæna, and the cave-lion, whose remains are so abundant in Belgium, are not as yet known to have existed in Ireland, though they, especially the former, were plentiful enough in England. This is worthy of special remark, because all the animals, whose remains have hitherto been found, are such as have, or may be supposed to have had, to some extent, aquatic habits; but I am not aware of any case in which animals of the feline race have been known to take to the water further than for quenching their thirst.

On the other hand, it is quite conceivable that any of the species of bears, wolves, elephants, hippopotami, oxen, deer, boars, &c., named in the list above, may have been able to cross narrow channels, either by swimming, or on rafts of ice, from Britain. It is

* Trans. Brit. Association, 1834, p. 658.

a matter of certainty that towards the close of the Drift period the channel which separates Scotland from the North of Ireland was much narrower than at present; and across this narrow channel, with land full in sight, the animals which sometimes swim may have made a passage from Britain, from time to time. This would be at period subsequent to the general glaciation of the British Islands.

In connexion with the subject of the Post-Tertiary fauna, I wish to call attention to the publication of two works, one of which was recently exhibited at a meeting of the Society, the "*Reliquiæ Aquitanicæ*," with descriptions and illustrations of the extinct fauna and works of art of the aborigines of Central France, found in the caves of Perigord by MM. Edward Lartet and Henry Christy, edited by Professor T. Rupert Jones, F. R. S. The other, "*On the Dentition and Osteology of the Maltese Fossil Elephants*," by Professor J. Leith Adams, F. R. S.

Microscopic Structure of Rocks.—The next subject to which I would direct the attention of Irish geologists is the microscopic structure of rocks—a subject to which my predecessor, Professor Macalister, drew our attention in his Anniversary Address (1873), in which he showed how much has been done in this branch of investigation by continental petrographers, especially by Zirkel, Rosenbusch, G. Rose, A. von Lasaulx, Tschermak, and others.

In England, Sorby, Allport, Forbes, Ward, and a few others, have taken up the subject with energy and success, but those in this country who pursue it are still few. Considering the large number of able microscopists who assemble together monthly at the reunions of the Microscopic Club in this city, it is surprising that the captivating study of rock structures, by the aid of the microscope and polariscope, has not attracted more observers. I trust that ere long an improvement in this respect will take place, and that the vast varieties of sedimentary, metamorphic, and plutonic rocks occurring in Ireland will be subjected to the searching scrutiny of the microscope.

There is one branch of this study which is yet very much in its infancy, and for the pursuit of which the rock-masses of Ireland present peculiar facilities. I refer to those structural changes undergone by rocks in passing from the original to the metamorphic condition. A series of observations, carried on with a view to determine the character and successive stages in the changes which hornblende rocks, gneiss, various schists, serpentines, and quartzites undergo in their progress from their original condition, would be of great interest, and would open a field as yet not much trodden. I therefore commend this subject to Irish petrographers.

Wealden Boring.—Fellows of the Society are aware that for the last two years an attempt has been in progress to solve the mystery of sub-Wealden geology by actual boring experiments. As British geologists are tolerably familiar with the range and distribution of the superficial deposits, they are naturally desirous of extending their knowledge to those which lie concealed at considerable depths, and in

many cases this can only be accomplished by actual mining or boring experiments. Both are now being carried out with facility, owing to modern appliances; and while some of our coal-shafts reach the depth of nearly 3,000 feet, the skill and perseverance of Prussian engineers have succeeded in penetrating to a depth of 5,570 English feet at Sperenberg, 25 miles south of Berlin, by boring.* The time seems, then, to have come for solving the problem regarding the nature and position of the rocks below the Weald of Kent and Sussex. The nature of the problem itself may be briefly stated. It is known that the Carboniferous and Devonian rocks of France and Belgium are thrown into a series of sharp folds, the axes of which range in nearly easterly and westerly directions, by Aix-la-Chapelle, Liege, Namur, towards Boulogne and Calais, where they are overspread by Cretaceous formations, which rest upon their upturned and denuded edges. From this point, westward, they are concealed from view by the waters of the English Channel, and along the south of England by mesozoic formations, until they (the Carboniferous rocks) emerge into day, in Somersetshire; and it is the opinion of physical geologists, amongst whom may be named Mr. Godwin-Austen, Professor Prestwich, and Professor Ramsay, that the flexures along the line of the Mendip Hills belong to the same system as those by which the Franco-Belgian Carboniferous rocks are influenced. It is quite possible, in fact, that one or more coal-bearing troughs may occur beneath the Wealden, or Cretaceous rocks, south of the Thames Valley, which, if discovered, would add materially to the known coal-resources of our island. But whether such concealed coal-basins occur or not, it is desirable we should know something more than can be done by mere conjecture, or inference, regarding the arrangement of the Palæozoic strata under the south of England, and every experiment is likely to add further data for the solution of the problem. Judging by analogy with the Belgian district, and from other considerations, there is every probability that the Permian and Lower Mesozoic series are absent under this region, and that after passing through the Wealden and Upper Oolite series, we should enter the Carboniferous and Devonian rocks.

In order to determine this point by actual experiment, a site was selected at Netherfield, near Battle, in 1872, by a committee, of whom the most active member was Mr. Henry Willett, F.G.S., of Brighton, who undertook the rather onerous duties of hon. secretary and treasurer. The contract for the work was taken by the Diamond Boring Company, and by the end of June last, a total depth of 1018 feet was attained. Here, however, the boring apparatus broke, and remains fast, and it is now proposed to make a fresh start in a new locality, near the old, as the engineer of the Diamond Boring Company considered that less time would be lost in taking

* See Letter by Mr. Bristow, F.R.S., on this boring in "Geological Magazine," Feb., 1875, p. 95.

this course than in endeavouring to recover the detached portions of the boring-rod.

The company undertakes to bore to a depth of 1000 feet (including lining the tubes) for £600, and to go down to 2000 feet at rates of about £50 for each 100 feet.

The results already attained are of considerable interest. Although the Palæozoic rocks have not been reached, the base of the Wealden series has been determined, and the presence in it of beds of gypsum; also the thickness of the Kimmeridge clay in that part of England has been ascertained. When the rods broke, the Oxford clay had been entered, while the Portland limestone, the coral rag, and calcareous grit were found to be altogether absent.

It appears from a statement by Mr. Topley, F. G. S., that, at a depth of about 290 feet from the surface, the Wealden beds were passed through, and the Kimmeridge clay entered; this extended to a depth of about 990 feet, giving 700 feet as the thickness of that formation, below which the Oxford clay, with *Ammonites Jason*, seems to have been penetrated.

Her Majesty's Government, acknowledging the national importance of this undertaking, have come forward to assist, but not to supersede, the efforts of private individuals; and let us hope that, ere long, the problem of the depth and position of the Palæozoic rocks under the south east of England will receive fresh light by the success of the sub-Wealden boring.

Nature of the Oceanic Bed at great Depths.—The observations which have recently been made on the nature of the sea-bottom at great depths by the naturalists on board H. M. Ship "Challenger" are of so great interest, as throwing light on the origin of several geological formations, that I cannot refrain from referring to them here.

From the examination of the bed of the North Atlantic, made in the year 1860, by the officers of H. M. Ship "Bulldog," it became known that the deep central regions of that ocean are formed of a calcareous ooze, composed chiefly of the little shells of Foraminifera, chiefly of the genus *Globigerina* with some siliceous shields of *Polycystinæ*, to which the name of "*Globigerina* ooze" was in consequence given.* It was soon recognised by geologists that in this foraminiferal ooze we have a modern representative of some of those great calcareous formations, such as the chalk of the Cretaceous and the Nummulite limestone of the Tertiary period, which are made up of the calcareous shells of foraminiferal animals, but in which the remains of molluscs, echinoderms, sponges, and crinoids are occasionally present.

Several questions remained, however, to be determined; amongst these we may select the following:—First; do the foraminifers, when living, repose on the sea-bed itself at the great depths

* For an interesting account of these deposits see Dr. Wallich's Paper, in "The Quarterly Journal of Science," vol. i., p. 37. With Plate.

attained, or do they inhabit the upper strata of the ocean, and only sink to the bottom when dying or dead? Secondly; has the "globigerina ooze" itself any limit of depth, or does it extend to the most profound regions of the ocean? To these questions the recent observations by the officers of the "Challenger," particularly of Professor Wyville Thomson, F.R.S., the director, and Mr. Murray, his assistant, offer the most satisfactory answers.

As regards the question whether the foraminifera live in the upper strata of the ocean, all the evidence points to an affirmative reply. The towing-net has been carefully kept employed at depths down to about 150 fathoms while the dredge has been at work at all depths down to 3150* fathoms, and a comparison made of the contents of each. This has been done, not only over the deep waters of the Atlantic Ocean, but also throughout the regions of the Southern Ocean, from the Cape of Good Hope to Australia; and it may be stated that the results of these observations, where remote from land, are (within certain limits) remarkably uniform. One result, indeed, is quite constant. The towing-net brings from the shallow strata of the waters the living representatives of the *Globigerina*, the *Pulvinulina*, and *Orbulina*, whose dead shells lie on the bottom, hundreds or thousands of fathoms below. Being dead, the foraminifer shells of the bottom are very different from their living representatives which swim about in the upper strata. Of these latter Prof. Wyville Thomson gives some drawings, taken from specimens captured in the towing-net; and the general conclusion he arrives at (though contrary to his former opinion) is that "the bulk of the material of the bottom in deep water is, in all cases, derived from the surface."†

The second question which (as I have stated) remained for solution, viz., whether there is any lower limit of depth to the "*Globigerina* ooze" itself, has also received an affirmative answer, which I regard as of exceeding interest to geologists, as indicating the probable limits of depth at which such formations as the White Chalk and Nummulite Limestone were deposited. The observations of the naturalists on board the "Challenger" have led to the discovery of a limit beyond which the calcareous ooze does not extend, although the waters of the ocean above are swarming with the very same living bodies as those which abound over the ground formed of *Globigerina* ooze itself; this limit may be placed at about 2200 or 2300 fathoms of depth. Upon passing this depth, a change comes over the whitish calcareous ooze; it passes into grey calcareous clay, and this again at a depth of about 2400 fathoms, into reddish clay, in which all traces of calcareous matter have disappeared, or nearly so; the clay being found to consist of silica, alumina, and oxide of iron, with occasionally manganese. Organic structure has also disappeared, and it might at first sight be supposed that some under current was employed in drifting the finest mud from some far-off sources.

* Proc. Roy. Soc., Lond., vol. xxiii., p. 40.

† *Ibid.*, vol. xxii., p. 427.

A little further observation, however, has led Professor Thomson and his associates to a different conclusion, and one which commends itself to the judgment; this conclusion being that the red clay is in reality only the *residuum* of the organic bodies after all the carbonate of lime has been dissolved out of them—that it is in fact, to use Professor Thomson's own expression, but *the non-calcareous ash* of the foraminiferal shells.

The question then arises, how has the calcareous matter of the shells been dissolved and carried away? This question is not difficult to answer, for it has been long known, by the observations of Professor Bischof, that the waters of the German Ocean (and we may presume of the Atlantic) contain five times as much carbonic acid as is necessary to retain in solution the carbonate of lime dissolved therein.* These observations have been extended and confirmed by the officers of the "Challenger," who find that the quantity of carbonic acid increases generally with the depth, the amount in the Southern Ocean being found to vary from 0.0373 gramme per litre near Kerguelen, in surface water, to 0.0829 gramme per litre in bottom water, when close to the Antarctic ice.

Now, it is evident that on the death of each little foraminifer, the shell becomes exposed to the action of the carbonic acid during the long period which it requires to slowly sink down to the great depths of the central oceanic bed. The time required for reaching depths down to about 2000 fathoms is apparently not generally sufficient to dissolve away the calcareous matter of the shell; but when the depth exceeds this, the shell gradually succumbs, and the additional depth of 200 or 300 fathoms is sufficient for its dissolution. Nothing then remains but the red insoluble *residuum* of silica, alumina, and iron-oxide, which make up the remarkable "Red-clay formation" of the profoundest depths.

Assuming, then, what is at least probable, that during the Eocene and Cretaceous periods the waters of the ocean contained about the same proportion of carbonic acid as at the present day, and what is equally probable, that the habits of the Cretaceous and Eocene foraminifera were similar to those of the existing ocean, it may be inferred, that the great calcareous formations of those periods were formed at depths which did not much exceed 2000 fathoms, and generally fell very much within this limit. If, on the other hand, it be asked, whether we have any formation amongst those now entering into the composition of the surface crust resembling in appearance and origin the "Red-clay formation" of the Atlantic and Southern Ocean? it may be replied that it is very doubtful if such exists, as it is improbable that any of our known formations were formed at greater depths than 2000 fathoms. Certainly, the red-coloured formations of the Devonian, Permian, and Triassic periods do not owe their origin to operations resembling those now going on at these enormous depths.

* "Chemical Geology," vol. i., pp. 176–178.

Valleys and Faults.—The appearance of a book dealing with questions of structural geology from the pen of an Irish geologist is of so rare occurrence, that I cannot pass by in silence the publication of Mr. Kinahan's little work, "Valleys, Fissures and Fractures." The book itself abounds with descriptions of numerous carefully-observed phenomena connected with the physical geology of this country; but, its main purpose seems to be to call the attention of observers to the close connexion between physical features of hill and dale and faults or fissures in the earth's crust. The author thinks, with, perhaps, some truth, that in the interest and enthusiasm caused by the modern views of the origin of physical features, of which Professor Ramsay may be considered the chief expositor,* too little account has been taken of the effects of faults and fractures, which must at the time they were formed have resulted in the production of surface irregularities. Now, any one who denies (and I am not aware who they are) that there is any connexion between some modern valleys and ancient fractures of the strata, must have but a limited acquaintance with structural geology; but sometimes, owing to the enormous amount of denudation which has taken place since the faults were produced, the original connexion between faults and valleys, or escarpments, has become less obvious, or has been entirely obliterated by subsequent terrestrial changes, which have established newer systems of river drainage in the same district. Professor Ramsay, when describing the valley of the Wye, in the work already referred to, puts the case very fairly when he observes, "For long it was customary to attribute such breaches in escarpments, and indeed valleys in general, to disturbances and fractures of the strata, producing a wide separation, and actually making hills. But when we realise that thousands of feet of strata have been often removed by denudation since the great disturbances of the Welsh strata took place, it becomes clear that the present valleys are in no way connected with them; for even if there be dislocations or faults in some of the valleys, these faults when formed were, as far as regards the present surface, thousands of feet deep in the earth. All they could do might have been to establish lines of weakness along which subsequent denudation may have excavated the valleys."†

There are, indeed, numerous instances in Britain where faults accompanied by very great displacements of the strata, and of newer date than the Triassic period, have left on the surface no traces of their influence whatever. A district well known to myself—South Lancashire—affords numerous instances of this kind. The coalfield of that country is traversed by faults of varying amount, up to 3000 feet, the amount of the displacements being capable of accurate determination by the relative positions of known coal-seams on either side of the faults; yet these great

* See "Physical Geology and Geography of Great Britain," by Professor A. C. Ramsay. 3rd Edition 1872. Also, Professor Geikie's "Scenery and Geology of Scotland."

† *Op. cit.*, p. 208.

displacements are not traceable on the surface by any conspicuous features. The denudation which accompanied and followed the formation of these great fractures has been of so sweeping a nature as to have levelled down the whole surface of the country.

Again, in the Cotteswold hills of Gloucestershire, remarkable for deep valleys and numerous escarpments, the numerous parallel faults by which the Oolitic beds are traversed only occasionally run in the lines of the valleys, but more frequently cross them.

On the other hand, there are some dislocations of such magnitude, like that of Bala Lake, estimated by Professor Ramsay at 11,000 feet,* that subsequent denudations have been unable entirely to obliterate the original valleys or lines of escarpment to which they gave rise, and they continue lines of depression to this day; another case is that of the Calder-Valley fault of Lancashire and Yorkshire.

In reviewing the whole question (only here touched upon), it must be admitted that, unless in cases where there are faults of surpassing magnitude, such as those I have mentioned, lines of valley and escarpment are established and perpetuated rather by the swellings and depressions of the crust over large areas, which have given rise to systems of drainage in certain directions, than by faults. Should a fault happen to lie in the direction of one of the streams thus originated, the stream will naturally select this line as the most convenient for the flow of its waters, and a valley will be formed along the line of the fault which will not be easily forsaken.

Space forbids me to pursue further a subject on which so much might be, and has been, written. I am satisfied that the interpretation of the physical features of the Earth put upon them by the modern school of British geologists (resuscitated from the days of Playfair and Hutton), is, in the main, true; and in this respect, if in no other, British geologists are in advance of their Continental brethren of the hammer.

It only remains for me to thank the Officers and Fellows of the Society for their support during my tenure of office, and to bespeak a still more zealous support for my successor, the distinguished author of the *Industrial Resources of Ireland*.

* That is, where it traverses the country N.W. of Aran-Mowddy; see "Geology of North Wales," Mem. Geol. Survey, p. 36.

XI.—THE ESTUARY OF THE RIVER SLANEY, CO. WEXFORD. By G. H. KINAHAN, M. R. I. A., &c., District Surveyor of the Irish Geological Survey.

[Read March 10, 1875.]

THE eastern portion of the Co. Wexford, in the neighbourhood of the sea, is, for the most part, low lying, and covered principally with Post-glacial drift, consisting of gravel, sands, clays, marl, and glacialoid or glacial-like boulder clays, with which are associated, in a few places, small patches of normal glacial drift. The newer deposits were accumulated at different times; the major portion in a sea that was between 300 and 350 feet higher than the present sea—that is, during the *Esker-sea period*; these drifts being contemporaneous with the Esker gravels of the central plain of Ireland. A second system of drift was formed when the sea was stationary, at a level between 70 and 120 feet higher than the Ordnance datum line; while a third system, which is necessarily very local, was banked up when the sea was stationary at about the 25 feet contour level.* The second and third periods, during which the above drifts accumulated, have been called respectively, the *Time of the 100 feet sea beach*, and the *Time of the 25 feet beach*, in a Paper published in the *Geological Magazine*,† and they will be so designated in this Paper. These gravelly and clayey drifts, in most places that are below the 300 feet contour line, obscure and cover the glacial drift and the older rocks (Carboniferous, Cambro-silurian, and Cambrian rocks; those of the last two divisions being usually more or less metamorphosed); but in all places where the older rocks are exposed, they are found to be much cut up and displaced by breaks, faults, or shrinkage fissures. The ages of the faults observed can be fixed within certain limits; they may be thus generally classed:—1st. Pre-Cambro-silurian faults; 2nd. Post-Cambro-silurian but Pre-Carboniferous faults; 3rd. Post-Carboniferous

* These different heights have to be calculated from the Ordnance heights, as the surface of the sea is not actually level—tides rising higher in narrow or confined seas than in wide oceans. On this account these different ancient beaches may vary more or less above or below the average horizon; as these ancient seas were subjected, as at present, to tides that rose in one place higher than in another. Thus the 25 feet contour beach is very constant round the Irish coast, but at various heights above the mean sea level in its vicinity. Thus, on the Galway and Mayo coast, it is about 17 feet above the mean tide; on the coast of Antrim and Down about 12 feet. In Dublin bay (where the large estuarine flat, on which a considerable portion of the city is built, belongs to this system) it is about 18 feet; and on the east coast of Wexford about 20 feet.

† “Glacialoid or Rearranged Glacial-Drift.” *Geol. Mag.*, Dec. 2, vol. i., March and April, 1874.

but Pre-glacial faults; 4th. Post-glacial faults, older than the Eskers; 5th. Faults more recent than the Esker gravels, some being later than even the gravels of the *Time of the 100 feet sea beach*; but all probably older than the *Time of the 25 feet sea beach*.*

We now proceed to the immediate subject of this communication, the formation of the estuary of the River Slaney. Into this estuary, as seems to be the case in all the estuaries of the large rivers in Ireland, very little *detritus* is brought down by the river; for, on account of the nature of the river valley, nearly all the *debris* brought into the river by its head-waters and muddy tributaries is lodged in the flats along its course; consequently, the silting up of the estuary must have been in a great measure due to marine action.

The present estuarine portion of the River Slaney lies between Enniscorthy and the open sea, the distance from the head of the estuary to the Rosslare and the Raven points, which form its mouth, being over nine miles. The upper portion is more or less narrow. However, in places, bays and guts branch off from it. To the N. W. of Wexford town, at Ferry-Carrig, it begins to widen, to form the reach known as Castlebridge bay; on the north of Wexford it again narrows for a short distance, but at the town it spreads out and forms the expanse called Wexford Harbour. The present estuary seems to have been excavated almost entirely in drifts of the Esker and 100 feet seas periods; in part, during "the time of the 25 feet sea beach," and partly subsequently.

When first formed it was evidently much deeper than it is at the present time. After it was excavated, it was separated from the open sea by the formation of an *Æolian* ridge, or bank of blown sand; subsequently to which it became very shallow, if not dry land; while afterwards the sea again rose; then, probably, the land rose a little, at a very recent time, thus enabling a large portion of the

* My colleague, Mr. J. Croll, of the Scotch branch of the Geological Survey, in one of his able papers, has pointed out that, as the ice-sheet retreated and advanced, the waters of the sea must have correspondingly fallen and risen, while the land remained comparatively stationary. This is a most important conclusion, as it accounts for the nearly invariable heights at which the margins of the different seas are found through the whole of Ireland; while if, as formerly supposed, the rise and fall of the *land* had produced the raised beaches, it would be scarcely possible that this approximate uniformity of level could have been preserved. This being accepted, ancient beaches, now found at exceptional heights, probably point to real movements in the earth's surface, due to local disturbances. In places, however, there seem to have been also slight local oscillations in the level of the land. This is suggested by the variations in the level of the Esker and newer ancient sea beaches. It also seems proved by the newer faults in the drifts, as these could not have been formed without the land going down on one side of them. Such slight local movements seem to have occurred in places on the Wexford coast during very recent times, as here and there raised beaches are found between the cliffs and the sea, while in general the sea is encroaching on the land. But some of these slight variations may be due to the difference in height of the tides in open seas and in straits.

tidal lands to be banked off and reclaimed during the last twenty-five years.

The proofs of the above statements are as follows. The marginal sands of the sea, of the *Time of the 25 feet beach*, can be recognised in different places along the upper portion of the estuary; while in the neighbourhood of Wexford Harbour the old marginal cliffs can be traced, they being well marked on the south side, in the vicinity of the Ross-lare coast-guard station, and on the north side at Ballinesker; in both places the *Æolian* drift ridge terminates against those cliffs; these marginal cliffs are cut in drift of the *Esker* period and the time of the 100 feet sea beach. North-west of Wexford, in the railway cutting, the *25 feet sea beach* was exposed, banked against gravels that may have belonged to either the *Esker sea period* or the *Time of the 100 feet sea beach*.*

As to the depth and nature of the estuarine deposits, very little can be ascertained at present; as only one excavation is known to have been made therein, viz., the sinking for the foundation of the west engine house on the north reclamation (North Flat),† which gave the following section :—

Section at the West Engine House, North Flats.

	Feet.
4. Mud,	16
3. Peat,	5
2. Grey muddy stuff,	1·5
1. Marl,	—
	22·5

This section shows that the estuary was formerly at this place about twenty-three feet deeper than at present. This, however, seems less than an average depth of the mud and other accumulations that have filled up the estuary, as the engine-house was built near the margin of one of the marl islands; and in other places the accumulations must be deeper, as has been proved by the quantity of filling stuff found necessary in various places for the building of wharves and railway embankments in the vicinity of the town of Wexford.

* In some places it is impossible to say to what time the gravels belong, as all are nearly similar to one another; the newer gravels being in general composed of the materials of the older, more or less shifted and re-arranged.

† Inquiries have been made to procure information as to the nature of the estuarine accumulations; and from them it would appear that no trials were ever made to prove the nature of the ground to be built on, preparatory to all the reclamation, railway, and harbour works that have been carried out from time to time.

The peat of the section at the west engine-house demonstrates that the land was, at one time, at least thirty feet higher relatively than at present.* The peat does not appear to be that which would grow in a "red or upland bog," but is more similar to that which would accumulate in a marsh, being more or less laminated, and mixed with clay, and containing the remains of aquatic plants, and such timber as the sallow; in fact, such a bog as that which now exists to the north-east of the Flats, in the neighbourhood of Curracloe and Ballinesker, the surface of which is a few feet above high-water mark. In the section at the engine-house, portions of oak timber were found, but they seem to have been logs which were probably floated into the bay during floods, having grown on the adjoining land, or on some of the islands; more especially as oak logs are not uncommon in the overlying mud. This, however, cannot be positively asserted, as so little is known about this deep peat: if, however, oaks grew and flourished in the places where the logs are found, it would necessitate the land having risen at least five feet higher than what is mentioned above, as the oak cannot grow, except on sufficiently drained soil.

The peat found associated with the other estuarine accumulations occurs at different levels. At the engine-house it is sixteen feet below the surface of the mud; to the east, inside and outside the Raven ridge, its surface is a few feet below the surface, or about low-water of neap tides; farther north, at Curracloe, inside the ridge, its surface is a few feet above the level of high tides, while outside the ridge it is a few feet below that level; and to the south, east of the South Flat, near the village of Rosslare, its surface is covered with a few feet of sand. Peat is reported to have been found to seaward of the banks, opposite Rosslare and Curracloe, in between four and five fathoms of water. This, however, has not been confirmed; as through the courtesy of Commander H. E. Stephens, R. N., Inspecting Officer of Coast-guards, I have received reports from the officers in charge of these stations, who state it is not known to exist in either locality; but Mr. James Regan, the officer in charge of Morriscastle, farther northward, writes:—"Turf is to be found in four fathoms of water in patches, north of the station;" the exact position on the chart, Sheet XV., being between "Rush bank" and the mainland. This depth, if we consider the turf here to be about four feet deep, would make the former elevation of the land to have been about thirty feet. The peat, as found in connexion with the North Flats, would seem to

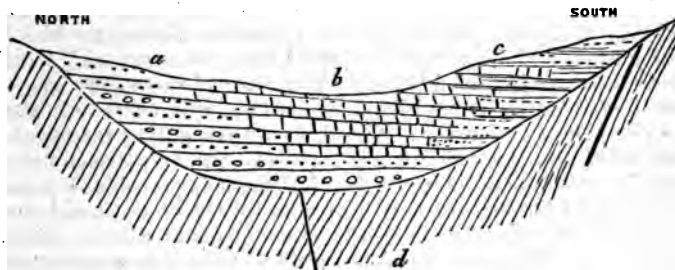
* Twenty-six feet of this height follows thus:—Mud sixteen feet, peat five feet, rise of tide at the site of the engine-house, prior to the embankment being built, five feet. This, however, probably does not represent the full height at which the land must have been when the peat began to grow, for it has been shown in a previously published paper ("Peat Bogs," London Quarterly Jour. of Science, vol. iv., N. 8.) that peat while growing is much thicker than it will be after subjection to pressure, and the five feet in thickness of compressed peat here found under the mud must represent a much greater thickness of growing bog. Hence, therefore, we take as a probable minimum thirty feet.

indicate that the bog was first flooded by the rising sea, in the vicinity of the present channel, from which the waters spread southward and northward, while, from some cause or another, the bog at Curracloe was never flooded, but continued growing to the present time. In some places inside the Raven bank, also near Rosslare, there seems to be an upper formation of peat.

From the peat we also learn that the *Æolian* ridges have moved landwards, since they were first piled up, the peat being under and outside them. The material of these ridges travels principally from south to north; we should, therefore, expect that the embouchure of the estuary would be situated towards the north, and not in the centre, as at present. Indeed, there is a tradition that, at one time, it was so placed, and it is even stated that it is so marked on old charts, but none of these are now forthcoming. Prior to the reclamation of the North Flats, it is said, there were three openings in the Raven ridge, through which it was possible for boats to pass at high water; but since those inlets were stopped, they have become filled up with *Æolian* drift. If such openings existed, it would seem to suggest that, in the northern portion, there were different breaks into the estuary, some of which may have been at different times considerable; but the present embouchure was probably for a long time the principal one. This subject we shall return to again, when we will give suggestions as to the form and position of these ridges.

Although the present estuary is principally excavated out of, comparatively speaking, recent drifts, yet it is quite apparent that, in ages long past, other valleys, probably either bays or estuaries, occupied nearly the same site. The farthest point to which we can go back with certainty is the denudation prior to the deposition of the Carboniferous rocks, during which bays, ravines, and guts were excavated along the breaks and faults that traversed the Cambro-Silurian and Cambrian rocks. In the hollows thus formed, the Carboniferous rocks were deposited, and the main currents in the seas of that period (as was general in the deposition of the Carboniferous rocks in all portions of Ireland with which I am acquainted) were generally directed from southward to northward. This is proved by conglomerates, sandstones, and other such rocks having been deposited on the weather-beaten open north shores of the bays, and south shores of the islands; while on the sheltered shores, south of the bays, and north of the islands, still-water deposits, such as limestone, shales, and fine argillous sandstone, or grits, accumulated. One of these bays, in which the Carboniferous rocks were deposited, existed on the present site of Wexford Harbour, and from it a narrow branch ran south-west to the present Ballyteigue bay. There were also smaller guts extending from the main bay, one of which ran westward along the present valley of the Bishops Water. That these Carboniferous rocks were deposited in bays in the older rocks is evident, as shore beds (conglomerate, sandstone, &c.) exist at different levels along the margins, or ancient shores, while seaward, or towards the

centre of the tracts, such rocks graduate into limestones, as represented in the accompanying woodcut.



Diagrammatic section across the S. W. arm from Wexford harbour. Carboniferous bay.

- (a) Conglomerates and sandstones.
- (b) Limestones, bedded.
- (c) Fine argillous sandstones, shales, &c.
- (d) Cambrian rocks.

After the deposition of the Carboniferous rocks, other faults were produced, affecting not only the older rocks, but also the newer ones. It is often difficult to distinguish these faults when examining the older rocks; but in some places their age is evident, such as the north-east and south-west faults that extend through Castlebridge bay. Other post-Carboniferous faults have also been proved; one of the best marked being the fault in the valley of the Bishops Water. Along many of these faults and breaks, valleys were subsequently excavated, removing, prior to the commencement of the glacial period, a large portion of the Carboniferous rocks, and all the rocks belonging to any newer formation that had been subsequently deposited; also portions of the older Cambro-silurian and Cambrian rocks, leaving at the commencement of the glacial period a long narrow slightly winding valley, extending along the present valley of the Slaney, past Newtownbarry, nearly to Tullow, in the county of Carlow. That this valley was excavated along lines of breaks is quite apparent, as in no place do prominences of rock project into, or run across it, while all the rocks in its vicinity are shifted out of their original relative positions. That no rock crosses or appears in this valley is very remarkable, when we consider that, interstratified with the Cambro-silurian rocks, are numerous beds of Ingenite rocks (felstone, diabase, hornblende-rock, &c.), and their accompanying tuffs. This alone proves that the river valley must run along lines of fault. Even allowing that the valley runs along a wide fissure, denuded out of a dyke of fault-rock, it seems singular that in no place does a mass of these Ingenite rocks appear through the alluvium in the flats, as, during the formation of the fault-rock, unbroken masses of the Ingenite rocks ought to have been entangled in it, while subsequently these ought to have resisted

denudation better than the associated ~~tail~~, and might be expected to appear in the valley as isolated rocks.

In the cross-valleys and guts joining into the main valley, faults or breaks are also generally evident.* This valley, with its tributaries, probably was principally excavated by marine action, its bed being nearly level. The sea, however, must have been materially assisted by meteoric action, and probably the form of the valley was afterwards considerably altered by glacial action, while meteoric abrasion has since been in force. It would seem that, during the time of the great ice-sheet, the valley was more or less filled by glacial drift, but scarcely entirely, for, as suggested by Dana, it is probable that beneath the ice-sheet large rivers flowed in many of the valleys; and it seems likely that this was the case with the valley of the Slaney. After the ice-sheet had disappeared, and the waters of the Esker sea had power to denude the land, they more or less re-excavated the valley of the Slaney, and, at the time of their maximum height, they extended up beyond Baltinglass, more than sixty miles from the present embouchure of the estuary; after this time, if not previously, the river valley was continuous from its present source to its mouth.

At the next marked period of rest, the *Time of the 100 feet beach*, the sea formed a slightly winding fiord, about forty miles long, extending from the present town of Wexford to above Clonegal, in the Co. Carlow. In the middle portion of the valley of the Slaney the margin of this estuary can be traced, but in the lower portion it is more obscure. Its mouth seems to have extended in width from the high land immediately west of Wexford town to the high ridge of ground north of Castlebridge; while all or most of the land to the east and south-east was under water. The low land immediately north of Wexford was, probably, in part due to a shoal formed by the set of the tide off the high land on the west of the present town; but that it was not all so formed is proved, by a considerable portion being marl belonging to the Esker sea period.

The next recorded period of rest is that of the *Time of the twenty-five feet beach*, during which the estuary seems to have been excavated nearly to its present form; it then extended up the valley to about half way between Enniscorthy and Newtownbarry, while the Bays from it were, in general, considerably larger. During this time the Eolian drift ridge between Rosslare and Ballinesker probably began to form. The formation of this ridge may be due to either

* It is not only possible, but it is also highly probable, that different movements have taken place along the lines of the old faults, subsequent to the faulting immediately after the Carboniferous period. Any movement that took place during the glacial period in the low-seated valleys has since been obliterated by the denudation and re-arrangement of the drift during the Esker period; and any that took place since the Esker sea period must have been small, otherwise the ancient sea beaches would not be now so continuous. On the neighbouring coast faults, which must have occurred after *The time of the 100 feet sea beach*, have been proved.

of the following causes: *First*. As the land rose the formation of a spit on a reef of rocks at the south shore of the bay, from which a ridge grew till it extended northward across the mouth of the bay. *Second*. The formation of a shoal outside the mouth of the inside bay (now Wexford harbour), which, as the land rose, was moved inwards, and modified into a continuous ridge.

Let us consider the second suggestion, viz., that the present ridges are modified shoals—for shoals probably existed, as shown by the materials that form the sea's margin. On the Admiralty chart* we find off Wexford harbour a broken line of shoals extending from off Greenore point to Cahore point, in which the widest break is opposite the mouth of Wexford harbour. Let us now suppose the land to have risen relatively forty-two feet (seven fathoms), and we should have a lagoon, bounded seaward by a ridge extending from Greenore to Cahore, and having in it two channels, one opposite the present mouth of Wexford harbour, and the other at the extreme north at Rusk channel. We supposed the land to have suddenly risen; but if it rose gradually, these shoals would be at the same time modified, being moved inward, and moulded into gradual wide curves—the centre channel, on account of the deeps inside, gradually deepening. This seems a probable solution of the formation of the Rosslare and Raven Æolian ridges; as during the *Time of the twenty-five feet beach*, shoals probably existed outside the inner bay, which, as the land rose, were modified into a ridge that had channels through it, at the centre and towards the north; the centre one gradually deepening on account of the deeps inside it; while those to the north became gradually filled up, on account of the northward drift of the sand. The northward drift of the sand would also account for the formation of the Dogger bank, at the entrance to the harbour, as the drift of the sand would tend to fill up the central channel, while the flow of the water out of the estuary would push it backward, and between the two sand, &c., would be piled up to form the Dogger bank. Subsequent to the banks having been formed by the tidal action, wind-blown sand added considerably to their height; some of the hills and short ridges in this Æolian drift being over fifty feet in height. After the Æolian ridges were formed, the waters of the sea gradually subsided, until eventually the land was relatively thirty feet higher than at present, when the bogs began to grow.

During all the time the land was rising above the level of the water, the estuary at first, and the river afterwards, were becoming more and more efficient at denudation; the latter, therefore, cut for itself a regular channel, its course probably being determined by previously existing deeps; and such deeps would probably exist somewhere about the present channel, as thereabouts there must be lines of breaks. Hollows along these lines of breaks were probably excavated prior to the Glacial period,

* Ireland, Sheet XV.

and, during the time of the ice-sheet, may have been the channel of an infra-glacial river; they may, indeed, have been filled up during the time of the *Esker sea*, but afterwards they probably would be more or less re-excavated by currents during the *Times of the 100 and 25 feet beaches*. The last current must have so deepened the channel that it could not since be filled up.

After the land had risen relatively thirty feet higher than at present, it began to sink, when the conditions of the *Æolian* ridge were as thus—the sea was encroaching on one side, while there was land on the other; consequently the ridge moved landwards before the sea, and instead of margining the bog, as at first, it now rests on it; while on the sea side of the ridge, the bog extends out below low-water mark.* When the sea rose high enough, the bogs were submerged, and mud deposited on them, until eventually, in the neighbourhood of the west engine-house, on the North Flats, the bog was sixteen feet below the surface of the mud. Near the end of the time during which this mud was accumulating, the land seems to have slightly risen, as the upper stratum is highly impregnated with iron, and separated from the subjacent mud by a stratum of shells. The lower portion of the mud seems to have been deposited in much deeper water than the upper stratum, for the following reasons: During the whole time that the muds were being deposited, considerable quantities of iron in solution must have come down in the waters of the Slaney, supplied by the decomposition of the Cambrian, Cambro-silurian, Granitic, and Ingenite rocks in the country drained by the Slaney. The most of this iron is found deposited in the mud above, and very little in that below, the stratum of the shells; it would, therefore, appear that, at the first, the water was deep, and the iron was carried away with the ebb of the tide; but afterwards the water became shallow, and a larger proportion of it evaporated, thereby depositing some of the solid matter contained therein, which was principally iron. That such a process is not uncommon may be perceived in many mountain streams, as during the winter floods the water in them is quite clear; while in the summer

* *Note in Press.*—It is possible that here, as in other places, the *Æolian* ridges did not exist until this estuarine land began to sink; but, as has been previously stated, shoals probably existed off this coast before the estuarine lands accumulated, and if they did, they probably moved inland as the land rose. It has been suggested against the supposition, that the ancient shoals were the nuclei of the present *Æolian* ridges—that they for the most part consisted of gravel and shingle. But I learn from the fishermen and the charts, that, although the present shoals for the most part are accumulations of gravel and shingle, yet in places they are wholly formed of fine sand. Furthermore, if the ancient shoals formed the nuclei of the present *Æolian* ridges the materials that were in them would long since have been carried northward by the tidal wave, and their place occupied by materials from the southward. It is, however, unnecessary, for the formation of ridges like those of Rosslare and the Raven, that offshore shoals should previously exist, as we know that the sea on a sinking coast line is inclined to form ridges across the mouths of shallow bays, and to heap up sand and the like on the margins of low level lands; thus eventually forming lagoons, similar to that of Wexford Harbour.

their water becomes thick and turbid.* That this change took place suddenly seems proved, by the shell-fish that inhabited the waters of the estuary having all died at once.

Since the North and South flats were reclaimed, there has been a remarkable alteration in the mouth of the harbour, as the Dogger bank has changed from a massive east and west shoal, lying off Rosslare point, into an elongated south-west and north-east shoal, that overlaps the Raven point; while the Raven bank, to seaward, near its termination, has been considerably added to. These changes are evidently due to the lessening of the quantity of water now flowing out of the lagoon, consequent on the cutting off of the large area of tidal lands. These vast and important changes have taken place principally since the year 1854, when the embankments of the South flats were finished.

XII.—ON THE TIDES OF THE AMERICAN ARCTIC ARCHIPELAGO AND THEIR INFLUENCE IN POLAR EXPEDITIONS. By the REV. SAMUEL HAUGHTON, M. D., F. R. S.

[Read April 14, 1875.]

I. SUMMARY OF ARCTIC TIDAL OBSERVATIONS ALREADY MADE.

THE tidal wave enters the Arctic Polar Basin by three distinct channels:—

1. By Behring's Strait,
2. By Davis' Strait,
3. By the Greenland Sea and Barentz Sea.

As to the first two of these tidal waves, I can offer some useful observations; but I know little of the third wave, beyond the fact, recorded by Captain Markham, that the tide wave No. 2, entering Smith Sound and Kennedy Channel, meets at Cape Frazer (Grinnel Land), Lat. 80° N. with a tidal wave coming from the north, which I believe to be the wave No. 3, which has travelled round the north coast of Greenland, thus proving it to be an island.

1. *Behring's Strait Tidal Wave.*

Observations on this tidal wave have been made at—

- | | | |
|------------------|----|---------------------------|
| 1. Port Clarence | by | Captain Moore. |
| 2. Point Barrow | „ | Captain Rochfort Maguire. |
| 3. Walker Bay | „ | Captain Collinson. |
| 4. Cambridge Bay | „ | Captain Collinson. |

* This is remarkably exemplified in some of the streams in the West Galway hills, especially in the small river flowing out of the Maum valley into the Killary bay, at the village of Leenaun.

All these observations lead to the result that this tidal wave is a simple lunar semi-diurnal tide, without any complication of solar semi-diurnal or of diurnal tides, all of which seem, from some unknown cause, unable to enter the Arctic Basin through Behring's Strait, although the diurnal tide is well developed in many parts of the North Pacific Ocean. This tide has been traced eastwards as far as Victoria Strait, where it meets the Davis' Strait tide No. 2, entering Victoria Strait, from the north, through Bellot Strait and Franklin Strait.

[The Franklin expedition perished at the meeting of these two tides, which forms a line of still water and immovable pack ice. In fact the "Erebus" and "Terror" having become beset in September, 1846, were abandoned in April, 1848, having moved only fifteen miles during the eighteen months.]

It is extremely probable that the Behring's Strait tidal wave enters Banks or Maclure's Strait and passes as far eastward as the Bay of Mercy, where Maclure's Expedition was abandoned, in 1853, after two years' ineffectual attempts to enter Melville Sound from the West. I am persuaded that this failure was due to the meeting of the Behring's Strait and Davis' Strait tidal waves at the western outlet from Melville Sound. Unfortunately this important fact cannot be determined with certainty, in consequence of the apparent loss of the tidal observations made by Maclure in the Bay of Mercy in 1851-52-53; and by Kellett in Bridport Inlet in 1852-53. If these tidal observations could be discovered, they would throw much light on the theory of the tidal motion of this part of the American Arctic Archipelago.

2. Davis' Strait Tidal Wave.

This tidal wave is much better known than that of Behring's Strait. Observations upon it have been made at—

1. Fredericksdal	by	Missionary Asboe.
2. Godthaab	"	Dr. Rink.
3. Holsteinborg	"	Director Efferg.
4. Prøven	"	Assistant Bolbroe.
5. Frederickshaab	"	—
6. Port Leopold	"	Sir James Ross.
7. Bellot Strait	"	Sir Leopold M'Clintock.
8. Beechey Island	"	"Resolute" and "Assistance," and "North Star."
9. Griffith Island	"	"Resolute" and "Assistance."
10. Refuge Cove	"	Sir E. Belcher.
11. Northumberland Sound,	"	Sir E. Belcher.

This tidal wave in passing Cape Farewell has a luni-tidal interval of 6^h 22^m, which is increased (Inglefield) to 11^h 0^m at Upernavik, and to 11^h 50^m at Van Rensselaer Harbour (Kane). The diurnal element is well developed along the Greenland coast. On reaching the head of

Baffin's Bay, the tidal wave moves northward, through Smith Sound, and (according to Captain Markham), meets another tide at Cape Frazer.* The tidal wave flows also through Lancaster Sound to the westward to Port Leopold, where it divides into three branches, through—

- a. Barrow Strait (westward),
- b. Wellington Channel, Queen's Channel, and Penny Strait (northward),
- c. Prince Regent Inlet (southward).

The progress of the tidal waves may be thus estimated by the lunital intervals:—

	H.	M.
(a). Port Leopold	11	44
Griffith Island (Admiralty Tide Tables)	0	15
Dealy Island (")	1	48
Bay of Mercy, not given (Admiralty Time Tables).		
(The range is given at 2 ft. in the Bay of Mercy, and at 4 ft. at Dealy Island; this circumstance, and the presumed difficulty of fixing the time of high-water, is in favour of the tide at Mercy Bay being the Behring's Strait tide.)		
(b). Port Leopold	11	44
Penny Strait	0	15
(c). Port Leopold	11	44
Bellot Strait	11	48

All these tidal waves are complex, and consist of four well marked waves.

1. Lunar semidiurnal.
2. Solar semidiurnal.
3. Lunar diurnal.
4. Solar diurnal.

This tidal wave cannot, therefore, for a moment be confounded with the Behring's Strait wave, which is a simple lunar semidiurnal wave.

The western branch moves (as I believe) across Melville Sound, and meets the Behring's Strait tidal wave in MacLure's Strait. The northern branch proceeds regularly through Penny Strait to lat. 76°, showing no sign of meeting an opposing tide, although it would probably meet

* Captain Markham's remarks show that the diurnal element is well developed in the tidal wave south of Cape Frazer.

the Behring's Strait tide somewhere about 80° . The southern branch, as I have proved, meets the Pacific tide at the north entrance of Victoria Channel, where the Franklin expedition was abandoned. If the statement of the meeting of two tidal waves in Kennedy Channel be confirmed, it will diminish the chance of reaching the North Pole by that route, even though the northern tidal wave be not the Behring's Strait wave, which is highly improbable.

It is not at all unlikely that the Behring's Strait tidal wave may meet the united Atlantic waves to the north of Greenland, and at this side of the Pole; in which case it is probable that sledges will do more work than ships.

As it may be of use to determine quickly the character of the tidal wave, I now give a method of doing so.

II.—METHOD OF DETERMINING QUICKLY THE EXISTENCE OF A DIURNAL TIDE.

Hourly observations of the height of the tide, made for forty-eight successive hours, will determine accurately the diurnal tide for every hour of the middle twenty-four hours. Let h_1, h_2, h_3 be three heights of tide separated from each other by intervals of twelve hours, then the diurnal tide, at the period corresponding to the middle observation h_2 is given by the formula:—

$$D = \frac{h_1 - 2h_2 + h_3}{4} \quad (1.)$$

The time selected for making the forty-eight hours' observations should be when the Moon's declination is great (either north or south), because the diurnal tide vanishes with the declination of the Moon or Sun respectively. The expression for the diurnal tide is of the form,—

$$D = M \sin 2\mu \cos (m) + S \sin 2\sigma \cos (s) \quad (2.)$$

Where μ = Moon's declination.

σ = Sun's declination.

m = An angle that goes through all its changes in a lunar day.

s = An angle that goes through all its changes in a solar day.

At the time of equinox $\sigma = 0$, and hence the forty-eight-hour observation, if made at this time, and also when $\mu = 0$, would show the non-existence of a diurnal tide, although there might be really a large one. The form of equation (2.) shows the reason for directing the observations to be made when the Moon's declination is great.

As a rule, the diurnal tide is of considerable amount, both lunar

and solar, in all the branches of the Davis' Strait tidal wave; and in some cases the solar diurnal tide is actually greater than the lunar diurnal tide.

III.—GENERAL RULES FOR TIDAL OBSERVATIONS.

Much valuable time has been often mis-spent on tidal observations of little value, and great disappointment felt at the small results produced by most laborious and carefully conducted observations; whereas in sundry cases, a single month's observations, properly made, have given results of great value, although the observations themselves did not cost one-tenth part of the labour of other observations which gave but little result.

I offer the following suggestions for tidal observations, made for a lengthened period.

1. Hourly observations of height should be made for one month at the times of solstice and equinox.
2. At the intervening periods, in order to save the labour of the observers as much as possible, it is recommended (instead of noting the time and height of high and low-water each day) that the height of the tide should be registered every *four* hours of *mean solar time*. This would correspond with the times of striking bells, which would ensure punctuality and accuracy as to the time of observation, and the observation itself could be made in one minute. I should prefer observations made every *four* hours, for this reason among others, that the diurnal and semidiurnal tides could be at once separated, and discussed independently of each other.
3. The times of observation must be carefully kept to; but whether the exact hours, or a fixed number of minutes after the exact hours, may be decided according to the convenience of the observers.
4. Remark carefully that the times of observation must be according to *mean solar time*, not according to apparent solar time.

XIII.—ON SOME NEW LOCALITIES FOR UPPER BOULDER CLAY IN IRELAND.

By EDWARD T. HARDMAN, F. C. S., &c., of the Geological Survey of Ireland.*

[Read March 10, 1875.]

IN Mr. James Geikie's valuable work on the "Great Ice Age," as well as in a former memoir by him† on "Changes of Climate during the Glacial Epoch," the presence of an upper boulder-clay in this country

* This paper was read at the Meeting of the Brit. Assoc., Belfast (1874).

† Geological Magazine, vols. viii. and xi.

is hardly admitted, ~~save~~ in the north-eastern portion, where it is (~~now~~ ^{now} ~~doubtfully~~) allowed to exist. I propose, therefore, to mention some places where I have observed such a deposit, in the hope that others may perhaps be induced to look out for it elsewhere.

All through the counties of Tyrone, Armagh, and such parts of Derry as I have visited, the drift is well represented, covering a large portion of the district, and reaching in many places a thickness of over 100 feet. I believe it can be divided into at least three groups, following the classification of Professor Hull, Professor Harkness, &c., viz. :—

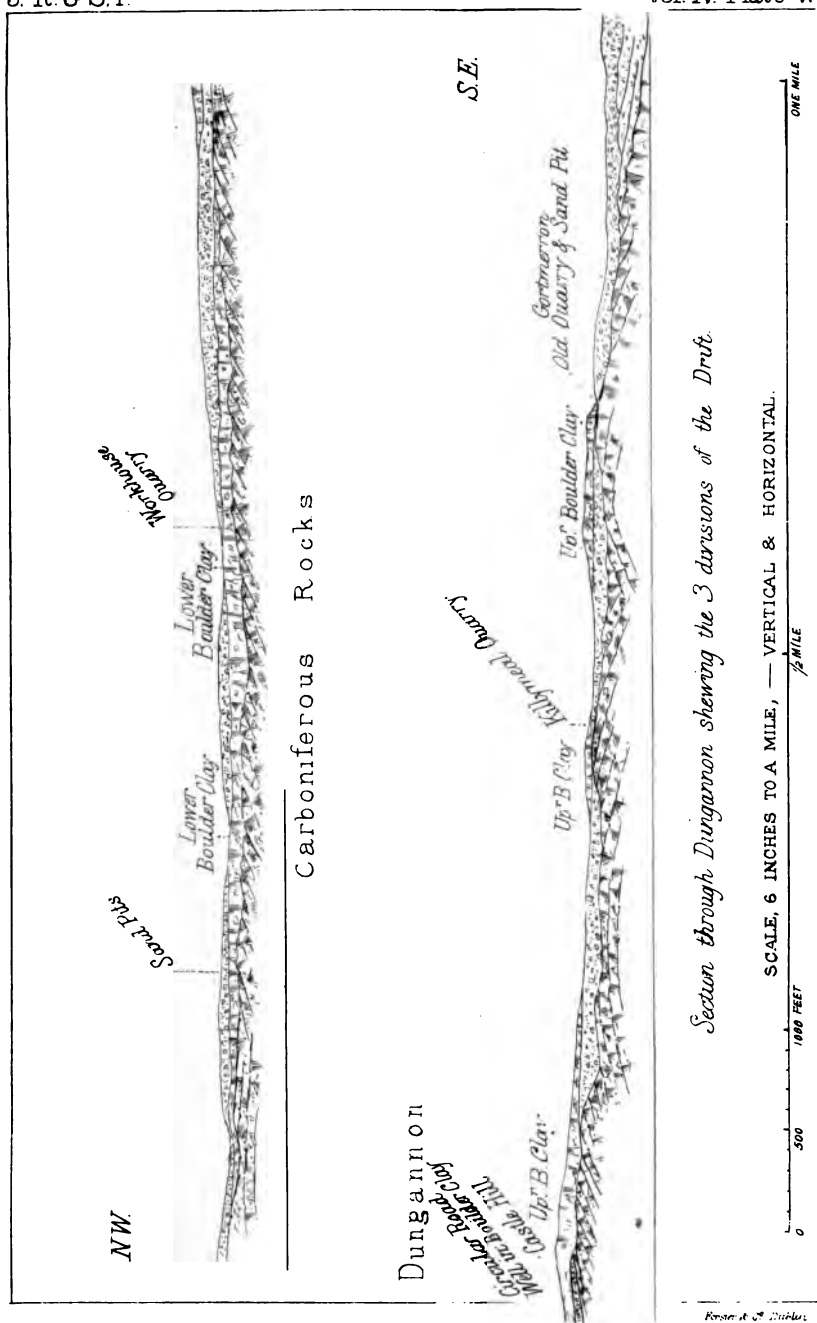
1. Upper boulder clay.
2. Stratified sands and gravels, with brick clays (middle sands).
3. Lower boulder clay, or till.

In some places there are peculiar esker-like hillocks of sand, which appear to belong to a still newer period, notably in the neighbourhood of Pomeroy and south of Cookstown. These may correspond to the kames and eskers of Mr. Geikie.

The lowest two members are well shown in very many instances, where well-stratified and current-bedded gravel and sand, with finely-laminated calcareous and non-calcareous brick clays,* can be seen resting directly on a denuded surface of till—which is in Ulster the local name for boulder clay. This is a hard, coarse, tough, blue or brown clay, unstratified, full of large angular and subangular scratched blocks, and but few pebbles. Both these formations can be traced over a great extent of ground; but the upper clay cannot be identified with certainty, except in a few places, resting on the summits of very high drift hills, where it has escaped denudation, or where a sufficiently deep cutting is found to expose the underlying sands. Thus, in the neighbourhood of Dungannon, the drift being extremely hilly, the whole three divisions can be found in places, and the accompanying section is constructed to show the way in which they succeed each other.† Commencing half a mile north-west of the town, at the Workhouse Quarries, there is thick yellow boulder clay, some twenty feet thick (about the 300 feet contour line), eroded, and capped with red stratified sand and current-bedded gravels, twenty to thirty feet thick. Going eastward, towards the town, there is at intervals the same sand and gravel continuing to a little above the 350 feet contour line. Higher up, to the top of the Castle Hill (444 feet), nothing but boulder clay is met with, and this of considerable thickness; for in the process of

* Calcareous clays containing *Cyprina Islandica*, *Turritella terebra*, and *Nucula oblonga*, which appear to be the equivalents of these, are mentioned by Portlock as occurring in the gravels of Bovevagh, Muff, &c., Co. Derry, but referred by him to the Upper Pliocene.

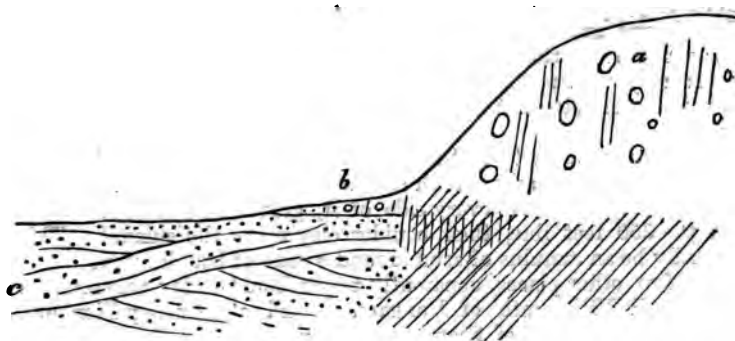
† See Plate V.



To illustrate Mr. Hardman's Paper on Upper Boulder Clay

sinking a well close to the Circular-road, about ten yards were gone through before reaching sand, which yielded water. Being often on the spot at the time, I saw that the stuff was really boulder clay, with large polished blocks, but rather sandy, and therefore differing from the lower till. On the side of this hill the sand and gravel come in again, evidently underneath a cap of boulder clay; and at Killymeal Quarry, where the ground rises again, hard sand, or sandy clay, with traces of stratification, full of boulders, with, at top, more orthodox till. It rests on the rock, but is doubtless upper boulder clay, for a little further on, the ground suddenly lowering, we have regularly-stratified sand and gravel resting on the rock in such a position as that it must underlie the clay. Then, the ground rising, again comes the boulder clay, resting on the rock on one side, but on the other evidently passing over beautifully stratified and current-bedded fine sand, such as is used in hour-glasses. This sand is exposed to within a few feet of the boulder clay, which towers above it to a height of twenty-five to thirty feet; but the junction is rather aggravatingly obscured by a slip of clay a few yards wide. Yet there can be no doubt the boulder clay caps the sand (see fig. 1). Further to the eastward, the sand and gravel continues to the end of the section.

Fig. 1.



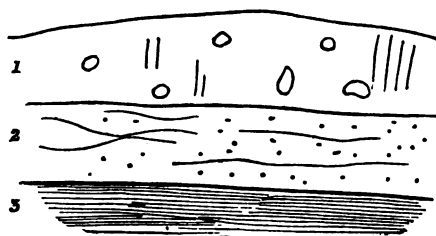
Gortmerron, near Dungannon.

	Feet.
(a) Boulder clay,	25 to 30
(b) ? Boulder clay or soil,	2
(c) Finely stratified sand, oblique bedding,	18.

Half a mile south of this section, along the Dungannon and Portadown Railway, there are several places where, from its position with respect to the gravels, as determined by the contour lines, the boulder clay must be the upper, for instance at Coolhill and Cookcush. In the former townland, the stratified sands, which are everywhere well

marked, rest on the Bunter shales, and are overlain by undoubted boulder clay, with large blocks (see fig. 2).

Fig. 2.



Section in railway cutting at Coolhill, near Dungannon.

	Feet.
1. Upper boulder clay, about	9
2. Stratified sand and gravel,	8
3. Red and green shales,	

A long tunnel through a drift hill, nearer Dungannon, was driven in boulder clay, containing large blocks. This must be an upper boulder clay, because towards the base of this hill, in the park, stratified sands and gravel are found between the 200 and 250 feet contour lines; while from the latter up to the top are numerous exposures of boulder clay, up to 333 feet. From the great slope of part of this hill, it is impossible that these sands could be resting on the boulder clay.

About one mile north-east of Dungannon is a conical hill, Mullagh-dun, 426 feet high, nearly as high as Castle-Hill. At the extreme base is boulder clay, then, on every side of it, gravel and sand to a little above the 350 feet line, then boulder clay up to the summit. This can hardly be an annulus of sand around a cone of boulder clay.

In a few other places, apparently upper boulder clay was seen, as at Windmill Hill, south of Dungannon, and at Drumagullion and Shanliss-upper, south of Stewartstown; while in Co. Derry, in the low ground to the north of Slieve Gallion, in a stream between Keenaght and Longfield, the following instructive section was seen:—

	Feet.
1. Yellow boulder clay, with polished blocks,	25
2. Well-stratified sand, somewhat current-bedded,	15
3. Hard brown boulder clay, with angular blocks,	10

50

It is true that some of these cases depend on their altitude for the proof of their superposition; for although the boundary between the

gravels and the clays can be traced tolerably closely, the actual junction is seldom visible, yet the frequent occurrence of such a state of things as thus noticed—i. e., boulder clay in the very low ground, then gravel to a certain height, and then boulder clay again, occurring with such persistence that, by the help of the contour maps, it is often possible to predict the exact place where each will be found on a series of hills of the same general level—leaves no other conclusion than that the gravels lie beneath the latter boulder clay. But in any case, the sections at Castle-Hill, Coolhill, Gortmerron, and Keenaght, afford ocular demonstration of the fact.

It seems to me that the drift of the more central parts of Ireland, especially that of the Queen's County, Carlow, and Kilkenny, is equally susceptible of a tripartite arrangement; for in various places, ranging from near Stradbally to Kilkenny, I have lately seen sections which admit, I think, of no other interpretation.

The general character of the drift here is, to all intents and purposes, similar to that of the north, except in the nature of its contents, these being here chiefly limestone blocks and pebbles, on account of which it has been hitherto described, somewhat vaguely, as "*Limestone gravel*."* Lowest of all comes hard, tough boulder clay, or till, full of large angular and scratched blocks and much local debris, such as Coal-measure rocks, &c., but very few rounded pebbles. It is often forty and fifty feet thick. Resting on an eroded surface of this is well-stratified coarse gravel, with paving-stones, fine gravels, beautifully-stratified fine sands,† highly calcareous in places, calcareous and non-calcareous mud (locally book clay), and calcareous tilestones and thin sandstones, due to infiltration of lime. This division, as well as the boulder clay, is found not only in the low-lying ground, but in many places on the coal-measure plateau, up to heights of 600 or 800 feet.

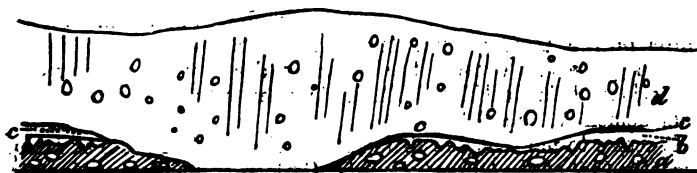
Next comes boulder clay, more or less sandy, with round and subangular limestone blocks, and *water-worn* pebbles (paving-stones), of which from thirty to fifty per cent. are well and *deeply scratched on the rounded surfaces*; the latter being so abundant that it often becomes a gravel, but is *never stratified*. This I consider to be upper boulder clay, and in fact it is sometimes found resting on an eroded surface of good stratified gravel. It often reaches a thickness of thirty to fifty feet, and is found in the low grounds as well as at a height of nearly 1000 feet on the Coal-measure hills, *e. g.*, one and a-half miles north of Ardough House, Queen's County, in many places along a stream.

* See Jukes' *Manual of Geology*, edited by Geikie, pp. 707, et seq., where it is all referred to as *Marine Gravel*.

† In a sandpit on the banks of the Barrow, near Carlow, I found two shells, *Purpura lapillus*, and a small bivalve shell, quite perfect. This I unfortunately mislaid before I could have it determined; but, having made a drawing of it, I have been able, with Mr. W. H. Bailey's assistance, to identify it as *Tellina solidula*.

At Coonbeg, in the River Douglas (six miles south-west of Athy), the two boulder clays are seen coming together. (See fig. 3.)

Fig. 3.



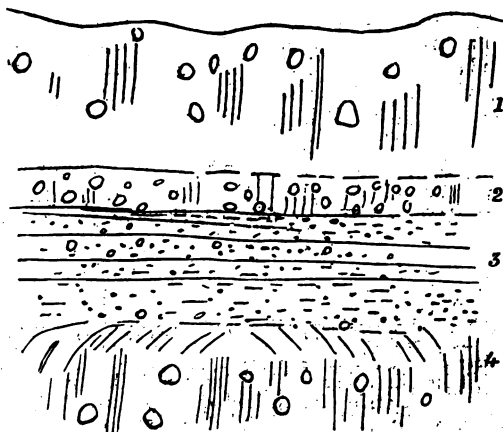
Section at Coonbeg, Queen's Co.

Upper Boulder clay resting on denuded surface of Lower B. clay.

	Ft.	in.
d. Coarse brown gravelly clay, with rounded pebbles and semi-angular blocks,	8	0
c. Distinct space between this and next bed, sometimes filled with gravel, sometimes with a spring of water,	0	6
b. Yellowish-brown mud, lying in indentations in underneath bed,	0	6 to 1' 6"
a. Blue, close till, with angular blocks, often very large,	2	0 seen.
	11	0

In same stream, one mile to west, the middle gravels came in. (See fig. 4.)

Fig. 4.



Section west of Coonbeg, Douglas River, Queen's Co.

1

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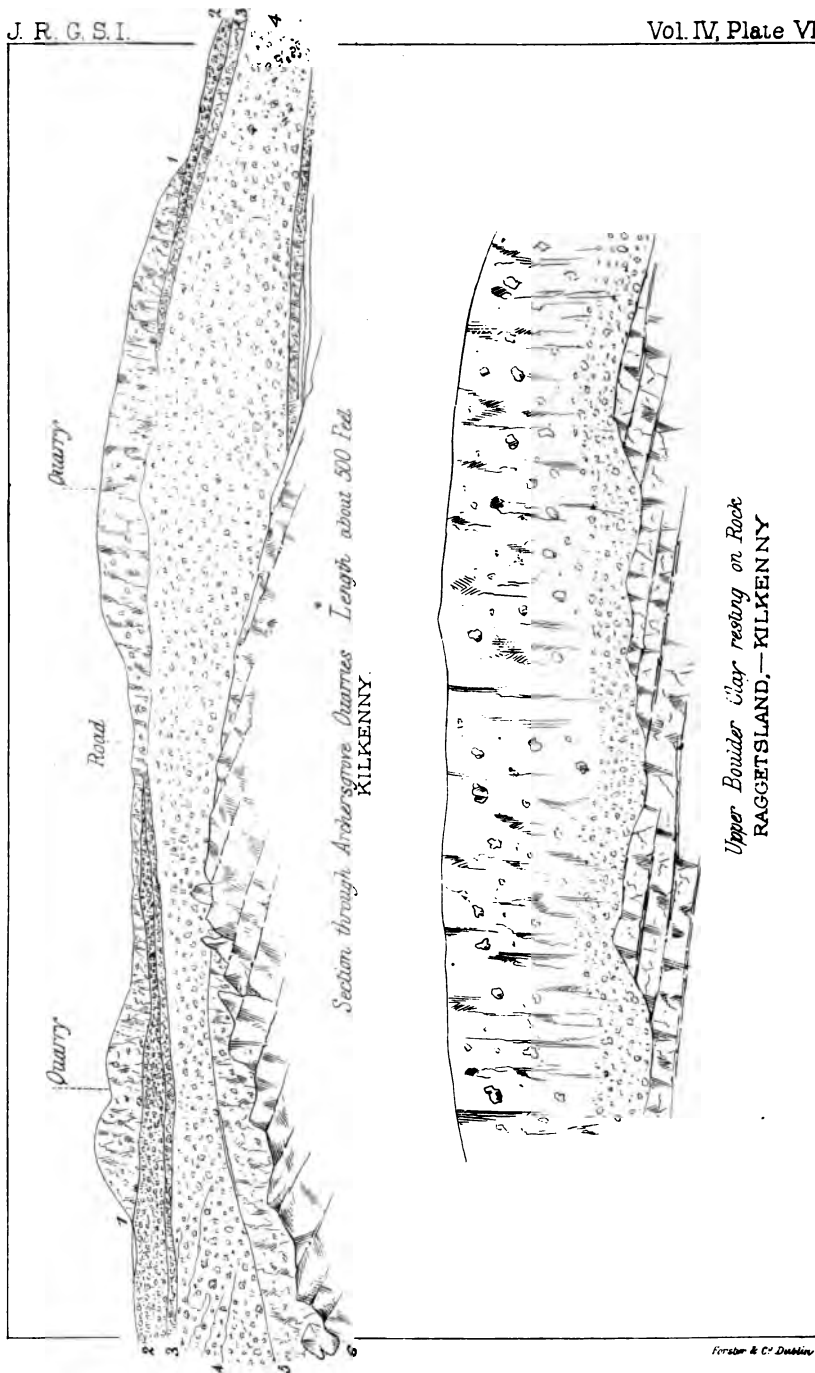
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10

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12





To illustrate Mr Hardman's Paper on Upper Boulder Clay.

	Feet.
1. Boulder clay,	18
2. Pebbly drift,*	3
3. Stratified sand and gravel, junction obscured,	25
4. Boulder clay, to level of stream, about	10
	<hr/> 56

At Carlow, the boulder clay is seen resting on the gravels. To the east of the town, under the railway embankment, between the Staplestown and Pollerton roads, the following is seen, length of section 200 feet (fig. 5):—

Fig. 5.



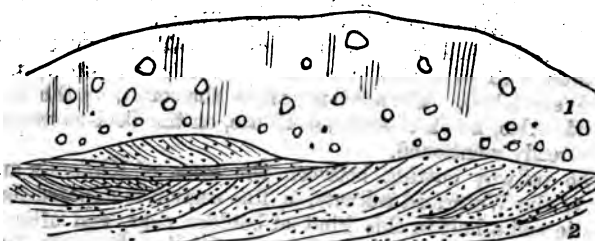
Upper Boulder clay on denuded surface of gravel. Railway embankment, Carlow.

	Feet.
1. Clay of embankment,	10
2. Yellow, sandy boulder clay, with a few bands of stratified gravels, and large semi-rounded blocks and paving-stones, beautifully striated,	6 to 8
3. Well stratified sand and coarse paving-stone gravels. Limestone pebbles at top, scratched. <i>Surface greatly eroded</i> ,	5

100 yards to the east the duplicate of this section appears, minus the embankment.

A mile and a-half from the above, and south of Carlow, near the gate-lodge of Brindale House, on the banks of the Barrow, the exposure is about ninety feet long, and reveals (fig. 6).

Fig. 6.



Upper Boulder clay on denuded current-bedded gravel, Brindale, near Carlow.

* Compare with section shown in Plate VI., at Baginbally, Kilkenny.

- | | |
|--|----------|
| | Feet. |
| 1. Upper boulder clay, with rounded and subangular blocks and paving-stones, well scratched. The clay sandy and brown, | 10 to 12 |
| 2. Grey fine gravels, well stratified, and with current-bedding. Surface eroded, and junction very distinct, 10 | |

 20

But, besides these localities for upper boulder clay, there is a considerable area covered with what I shall call "Paving-stone drift;" which, although the base is rarely seen, is most certainly upper boulder clay, and therefore deserves some attention. It consists of a confused mass of round, water-worn pebbles of limestone, usually the size of paving-stones, huddled together in a matrix, sometimes of sandy clay, sometimes of loose, gravelly sand: never stratified, though occasionally with rude lines of bedding. The greater part of the pebbles well and deeply scratched, striated, and polished on the previously rounded surface. Now, if this be not an upper boulder clay, what is it? It cannot be a lower boulder clay, for the pebbles are rounded by water action. It could not be relegated to the middle-gravel or to the esker series, for the pebbles are well scratched, and it is usually mixed up with clay and angular blocks. I have already noticed the occurrence of these water-worn and scratched pebbles in all the sections of upper boulder clay in the Queen's County and Carlow. All these characteristics would agree perfectly with its being an upper boulder clay.

The ice-sheet which gave rise to the upper clay must have passed in many places over the already rounded, stratified gravels with which this part of the country was covered, and would, of course, remove a great deal of them. This *detritus* becoming mingled together with clay and pieces of unrounded rock from places uncovered by drift, would result in a confused mass of pebbles, clay, sand, and boulders, and would naturally have more pebbles than boulders. This is exactly the kind of stuff that is visible all about Carlow and Kilkenny. Out of many sections I have seen of it I give the following. I should mention that it often occurs in esker-like hillocks.

On the Pollerton Road, near Carlow, a *boulder clay* is exposed for many yards, full of round, waterworn limestone pebbles, many of them well scratched. The same is seen to the south, on the Brown's-Hill Road. Also, north of Ardough House, on the Coal-measure table-land, as already mentioned.

In the railway cutting between the town of Kilkenny and the junction of the Waterford railway, a fine section is exposed for more than a mile and a half in this kind of boulder clay, and often thirty feet high. In two places, where the ground falls sufficiently, the clay is seen resting on stratified coarse sand and gravel. It is stuffed with pebbles, sometimes very large, and often round as cannon balls, these being well scratched in every direction, in some cases so deeply that a pencil could be laid in the striæ.

North of the town, near the workhouse, the same boulder clay is seen, about twenty-five feet thick, resting on thick stratified sands and gravels, rather tossed.

Half a mile west of this, at the graveyard, north of Green's Bridge, it is over twenty feet high.

At the south side of the Nore, at the black marble quarries at Archer's Grove, there is a very remarkable section, which is worth giving in detail. (See Plate VI.)

	Ft.	Ft.
1. Boulder clay or till, hard and yellow, with pebbles and large polished blocks, average,	10	to 20
2. Greatly tossed paving-stone drift, with large pebbles and blocks,	8	
3. Boulder clay,	2	
4. Greatly tossed coarse gravel, rude current bedding,	25	to 40
5. Hard, yellow, boulder clay, with well-scratched round pebbles in upper part,	12	
6. Limestone,		

But for the preponderance of scratched pebbles in the gravels (4) here, I should have taken this for a typical example of the three divisions. But I think what it denotes is, that the gravels, originally stratified, were in places dragged along by the ice, which eventually formed the upper boulder clay, and so became tossed and scratched. The upper part of the lower boulder clay being at the same time mingled with the gravels, and filled with scratched pebbles.*

I shall just mention one more section, which shows the upper boulder clay resting directly on the rock. It occurs in an old limestone quarry at Raggettsland, a mile south of the last, and consists of close, sandy till, about twelve to fifteen feet thick; but at the base it is full of the usual striated paving-stones for a depth of two to three feet. It may well be supposed that the glacier passing over the gravels just referred to, at the north, had relieved itself of the greater part of its load of pebbles before it had reached this spot. (See Plate VI.)

I believe these pebbly boulder clays can be explained on no other hypothesis than as being an upper boulder clay, even were they never found resting on the gravels, as I have shown; and it necessarily follows that, to provide materials for the accumulation of this over the great area where it is known to exist, and which I have here only partially glanced at, the middle gravels must have been previously spread over a district of no mean extent.

Since the above Paper was written, and read at the Meeting of

* I have lately (July, 1875) had the satisfaction of showing this well-marked section to Professor Hull, F. R. S., Director of the Irish Geological Survey. He considered that nothing could be clearer than the presence of the whole three divisions, and that the existence of the upper boulder clay there is beyond all doubt. The section extends for about 800 feet.—(*Added in Press.*)

the British Association at Belfast, my colleague, Mr. J. Kilroe, F. C. S., has brought under the notice of this Society a similar succession of Drift Deposits occurring in the Co. Sligo.*

Quite recently I have met with numerous other sections in the Kilkenny district, showing upper boulder clay resting on gravels. It is especially well shown on the Dinin river, near Jenkinstown, and at Dysart.—(*Added in Press.*)

XIV.—ON THE PRESENCE AND DISTRIBUTION OF FLUORINE IN CALCSPARS.

By CHARLES R. C. TICHEBORNE, Ph. D., F. C. S., M. R. I. A., &c.

[Read March 10, 1875.]

THE universal dissemination of some of the elements, particularly the more volatile ones, is a theory that gains a considerable number of adherents, and recent investigations, with the aid of increased facilities for research, tend to add weight to this not improbable view. The very general diffusion of lithia is an instance. Until the spectroscope was perfected, the metal was only known to exist in a few minerals such as lepidolite, petalite, &c.

In fact, the delicacy of our chemical tests seems to be the boundary or limit where we stop in determining the mineral diffusion of many of our elements. For some considerable time, I may say the last two years, I have been engaged in investigating the diffusion of fluorine in the animal concretions. I find that the element fluorine is an invariable ingredient of certain calculi, the calcium-calculi. This entrapping (if I may be allowed the term) of the element is due to the great affinity calcium has for fluorine, and the insolubility of the resulting fluoride of calcium. I thought it would be interesting to examine the mineral world, with a view to see how far this same trapping of fluorine had been carried out, and I submit the following note as a small instalment towards such an investigation.

It is, perhaps, not generally known that all the mineral phosphates of calcium used in the production of superphosphates are so impregnated with fluorine that the pipes connected with the apparatus used become jammed up with the silica deposited from the gaseous fluoride of silicon.

I have so far examined some of the calcspars in my possession, and find them to give the following results as regards fluorine.

F.

Fine specimens of calcspar on blend from Glendalough	marked trace.
Clear crystals from Derbyshire	trace.
Calcspar on galena from Glendalough	0·06.
Calcspar foreign, locality unknown	trace.
Fine Rhombohedron of Iceland Spar	marked trace.

* In a Paper entitled "On the Succession of Drift Deposits in the Co. Sligo." Read January 12, 1875.

In all these specimens the indication of the fluorine was got directly by mixing the powdered spar into a paste with sulphuric acid free from fluorine, and allowing it to act upon a surface of glass. The spar was powdered in an agate mortar, but was mixed with the sulphuric acid in a platinum capsule; the paste was then transferred to the surface of a perfectly new watch-glass; the whole was then covered with a second glass, and allowed to remain over sulphuric acid, under a bell jar for twenty-four hours at the ordinary temperature, and then warmed. A very minute trace of fluorine can in this manner be detected. By cleaning the glass and breathing upon it, the slightest corrosion will be perceived in the spot where the paste lay. Still more delicate traces may be detected by dissolving the specimen of calcspar in pure hydrochloric acid, precipitating about 1-10th or less of the calcium with carbonate of ammonium, and allowing the whole to remain twenty-four hours. The precipitate will contain almost all the fluorine present. There is this objection to the last process, that the operation runs the chance of introducing fluorine through the chemicals used. Thus I have always found great difficulty in getting hydrochloric acid free from fluorine. Pure distilled sulphuric acid seems pretty free from fluorine as an impurity, probably from the fact of the high boiling point. Nicklès recommends plates of quartz in preference to glass. I have never found any difficulty in getting watch-glasses that would stand the action of sulphuric acid for twenty-four hours.

It would be desirable to inquire how far the arragonites contain fluorine; they are generally said to be formed under temperatures and surroundings different from those under which the rhombohedral variety is produced.

The universal diffusion of some elements is something hardly realizable. To give an instance:—Absolutely pure carbonate of sodium and potassium cannot be procured; it is always slightly contaminated with chlorine. Chemically pure and crystallized tartrate of potassium and sodium on ignition assimilate chlorine from the atmosphere of the laboratory, and yield a product containing a slight trace. Now, it is just possible that fluorine is universally diffused like chlorine; and although, as regards this element, we may not have a great replacing source like the sea,* fluorine must be sufficiently general to have been rendered up to the entrapping powers of the calcium minerals, just as in the organic world the fluorine is always found locked up in the calcareous skeleton. Fluor-spar is very often found associated with mineral veins of zinc and lead, but the fluorine is equally found in the clearest and most perfectly formed isolated crystals of calcspar.

* Small quantities of fluorine have been detected in most of the rivers examined. See Nicklès, *Comptes Rendus*.

XV.—NOTE ON THE PRESENCE OF THALLIUM IN AN IRON ORE FROM PRUSSIA. By CHAS. R. C. TICHBORNE, Ph. D., F. C. S., M. R. I. A.

[Read May 12, 1875.]

THE specimen of ore, which I am about to describe, was one taken from my private collection, and examined with others for the metal thallium. It was an ore that had been sent from Prussia to the Dublin International Exhibition of 1865; and was accompanied by an analysis by Dr. Fresenius. There is no mention made of the presence of thallium in the original analysis. This circumstance may be readily accounted for from the fact that the mineral had been analysed but a short time after the discovery of thallium, and before the use of the spectroscope was much in vogue, and because traces of that metal cannot be detected by the ordinary application of chemical tests, for even the spectroscope fails to detect a minute trace of that element in such a mineral, when the solution in acids is directly examined. The other elements present give such a bright continuous spectrum, from D to F, that the slight flash produced by the volatile thallium is unperceived.

We presume that the specimen examined fairly represented the ore originally analysed, because, on performing a quantitative analysis the results were fairly concordant, except in a slight increase in the amount of zinc.

The specimen analysed was an extremely hard and compact ore, very fine grained and homogeneous in character, and having a specific gravity of 4·13. The ore contained (as analysed by myself) :—

Sulphur	47·02
Iron	39·58
Zinc	4·72
Copper	0·20
Thallium,	trace
Cobalt,	trace
Manganese,	trace
Arsenic	1·22
Lime	0·80
Magnesium,	trace
Silica, moisture, &c.	6·46

100·00

Premising that this is a mechanical mixture of blend and pyrites, it would be impossible to determine with which of these minerals the thallium was associated. Dr. Reynolds has found thallium associated with Irish cupreous pyrites.

The process adopted, as regards the separation of thallium, consisted in filling an ordinary combustion tube with the ore broken small, and subliming the sulphur into any convenient receiver. After the opera-

tion this sulphur was removed and finely powdered (this being essential for a successful manipulation, when only a trace is present). The excess of sulphur was dissolved out with bisulphide of carbon, and the small residue left, on treating with sulphuric acid, was directly examined in the spectroscope for thallium.

XVI.—ON THE MICROSCOPIC STRUCTURE OF A FRAGMENT OF "BAKED" OR INDURATED SLATE, FROM THE LOWER SILURIAN ROCKS, CLAREMONT HILL, NEAR DUNDALK. By PROFESSOR EDWARD HULL, F. R. S., F. G. S.

[Read April 4, 1875.]

FELING desirous of ascertaining the internal structure of slate which, from contact with igneous rock, had become "baked" or indurated, I selected a specimen from the Silurian beds on the western flanks of the Carlingford mountains, above Anaverna, near Dundalk, from which I had a translucent thin section prepared for microscopic examination, and the results have proved so interesting, and seem to throw so much light upon the cause of the induration of the rock in consequence of the "baking" to which it had been exposed, that I venture to lay them before the Society.

Nature of the Rock.—The rock from which the specimen was taken is of a dark grey colour, uniform in texture, hard and splintery. It might pass for a felstone, owing to its compact character and the absence of lamination, except in rare cases. As trap rocks abound in its neighbourhood, it has evidently been subjected to a high temperature, to which its hardness is to be attributed, though it remained to be ascertained what was the immediate cause of the hardening process. This was clearly revealed on placing the thin slice under the microscope.

*Microscopic Appearance.**—When observed with a low magnifying power (two-inch object glass, magnifying twenty-five diameters), there appeared numerous rounded and sub-angular minute grains of silica imbedded in a darkly-mottled matrix. A dark narrow band was observed to traverse the field of view, perhaps indicating a plane of bedding. The particles of silica did not, however, appear to be disposed in any particular direction as regards their longer diameters.

With a higher power, the matrix, or paste, resolved itself into a colourless translucent glass with reticulated structure, clouded, and containing dark grains, which, as the rock is magnetic, are doubtless composed of magnetite. With polarized light the little grains of silica exhibit a play of colours on rotating the analyser, while with crossed Nicols the colourless paste becomes dark—as in the case of ordinary glass. It thus appears that the grains of silica have retained their

* The microscopic appearance of unaltered slate is shown by Mr. D. Forbes, F. R. S., in his paper on "The Microscope in Geology," in *Pop. Science Review*, Oct., 1867.

original form and nature unaltered, but are bound together by a firm glassy paste.*

The question then arises, what may have been the material out of which the glass paste was formed? This question can be answered by referring to the following chemical analysis, kindly made for me by the Rev. Dr. Haughton, F. R. S., at the Laboratory of Trinity College, Dublin, which is as follows:—

Analysis of the Specimen of Indurated Slate, Dundalk.

Silica,	65·44
Alumina,	13·48
Peroxide of Iron,	2·16
Protoxide „	2·85
Lime,	8·08
Magnesia,	3·08
Soda,	1·94
Potash,	1·74
Protoxide of Manganese,	0·40
Water,	0·40

99·57

Specific Gravity, 2·815.

It is clear, from a consideration of the above analysis, that in this specimen we have all the materials for the production of a mineral glass at a low temperature, the alkalis being present in considerable proportions, lime, also, being more than usually abundant.

We may suppose, therefore, that in the original unaltered shale or slate, the silica occurred in two forms, first as free silica, in little grains, as seen under the microscope, and also in combination with the alumina to form clay. In the process of induration, and under a temperature considerably elevated, the clay entered into combination with the alkalis, forming a glass, while the grains of free silica appear to have remained unaltered. The black grains of magnetite which the microscope revealed are shown above to be present to the extent of 3·13 per cent., as determined for me by Mr. E. Hardman, F. C. S.,† together with a small quantity of manganese ore. Not a trace of carbonaceous matter remains in the rock, the dark colour of which is due to the presence of the magnetite grains, and to the clouded appearance of the glass paste, as seen under the microscope, and which is probably due to the residue of protoxide of iron which has entered into combination to form a proto-silicate of iron (see Appendix).

As regards the temperature at which the induration took place, it may be observed that, if the process had been in operation at the earth's surface, the temperature would probably be that at which ordinary

* The grains of silica are highly cellular; but, even with a microscopic power magnifying 800 diameters, no fluid cavities were observed.

† See Appendix.

glass fuses. But the induration having occurred at probably a considerable depth, the element of pressure comes into account, and, as the amount is altogether uncertain, no accurate determination of the degree of heat to which the rock was exposed can be arrived at. On this subject I have been favoured by a communication from Mr. G. Johnstone Stoney, F. R. S., which is appended to this paper.

It is obvious, therefore, that the stone has undergone, to a certain extent, a process of metamorphism; and that this metamorphism was on the point of developing felspar throughout the mass is shown by the occurrence, at one part of the edge of the slice, of some little prisms of triclinic felspar, confusedly mixed together. This portion is, to all appearances, not a fragment of a foreign rock, but a portion of the paste of the slate rock itself.

Seeing, therefore, that the original grains of silica are now bound together by a solid, glassy cement, instead of unconsolidated or granular clay, it is not to be wondered at that the soft slate has been converted into a compact splintery stone, approaching Lydian stone in hardness.

APPENDIX.

Note on the Proportion of Magnetic Iron-ore in the Specimen, by MR. EDWARD F. HARDMAN, F. C. S., of the Geological Survey of Ireland.

In order to arrive at some determination as to the amount of magnetite present, as there is no analysis of the unaltered rock, it must be assumed, either that all the protoxide is combined as magnetite, or that all the peroxide is so. The former is impossible, because 2.85 per cent. of protoxide would need 6.34 of peroxide to produce the compound, or 3.82 per cent. more than the rock contains. All the protoxide cannot therefore be so combined. On the other hand, regarding all the *peroxide* in that light, there would be 0.97 per cent. of protoxide required to form with it magnetic oxide, the amount of which would be 3.13, leaving 1.88 per cent. of protoxide in the glass or slag, probably as protosilicate of iron.

That all the peroxide belongs to the magnetite, is rendered not improbable by the fact of that mineral showing so abundantly under the microscope, while it is known to be usually, if not always, formed when the protoxide, or some salt of the protoxide susceptible of such influences, is exposed to the action of heat in the presence of oxygen or aqueous vapour. Thus, in the calcination of clay-ironstone (protocarbonate), a quantity of magnetic oxide is produced.*

It might be possible that a sufficiency of carbonate of iron originally existed in the rock, to give rise to the magnetite. Bischof gives a few analyses of clay slates containing it, and several of those containing carbonate of lime, in two cases as much as twenty-four to twenty-

* See Bauerman's *Metallurgy of Iron*, pp. 121-3; Percy's *Metall. Iron and Steel*, pp. 49-50; Fownes' *Man. of Chem.*, 10th Ed., p. 140.

six per cent.* In such rocks the heat which has partly melted the Dundalk slate would be quite sufficient to drive off the carbonic acid, producing lime and some magnetite; the former base would of course combine with the silica and alumina to form the glass or slag, together with any unaltered protoxide of iron, which last would add to the fusibility of the compound.

(*Letter from G. JOHNSTONE STONEY, F. R. S.*)

"DUNDEEM, Nov. 8, 1874.

"MY DEAR HULL,—You have shown that the temperature of which you are in quest lay between that at which the matrix of earthy materials would fuse, and that at which silica would fuse.

"The former of these, which fixes the lower limit of the melting temperature of the slate, depends on the composition of the matrix, and is too indefinite to admit of determination. But it would, I suppose, be safe to regard it as such a temperature as can easily be reached in furnaces.

"But the upper limit, the temperature at which silica would fuse, is known to be one not exceeding that of the oxy-hydrogen flame; and we have some very precise knowledge of this temperature from the investigation by Bunsen, of which you will find an account in the *Phil. Mag.* for 1867, Vol. ii., p. 489.

"It appears, from Bunsen's determinations, that the elevation of temperature above that of the gases before combustion cannot exceed 2844°C .; that at this temperature only $\frac{1}{3}$ rd of the mixed gases combine, that $\frac{1}{4}$ th more burns at temperatures of which 2024° and 2084° are examples, and that the rest of the combustion takes place at lower temperatures.

"It appears, therefore, that the elevation of temperature by an oxy-hydrogen flame is not the same at all parts, and nowhere exceeds 2844° ; and, as silica can be drawn into threads in the flame of an oxy-hydrogen blow-pipe, it follows that it must fuse at a temperature short of this, and which is probably a good deal over 2844°C . The metamorphosing temperature of the slate cannot have been so high as this.

"Yours, very truly,

(Signed)

"G. JOHNSTONE STONEY."

EXPLANATION OF PLATE VII.

FIG. 1. A portion of the thin slice of the indurated slate, magnified three diams. The little grains of silica appear in rounded or sub-angular, colourless specks, in a dull, brownish paste, containing black specks of magnetite.

FIG. 2. A portion of the above magnified twenty-five diameters, in which the grains of silica, the clouded glass paste, and grains of opaque magnetite, are more distinctly brought out.

* See Bischof's *Chemical Geology*, English Ed., vol. iii., p. 130, *et seq.*



Fig 1.

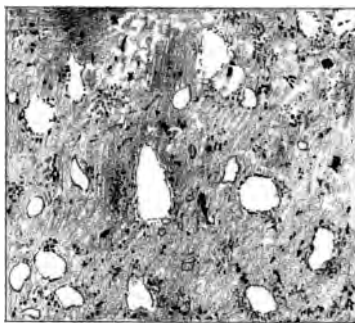


Fig 2.

MAGNIFIED SECTIONS OF INDURATED SLATE.

Fig 1. *Mag. 3 diams.*
2 25

Printed & Co. Dublin.

To illustrate Professor Hull's Paper on Baked Sl

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Fig 1.

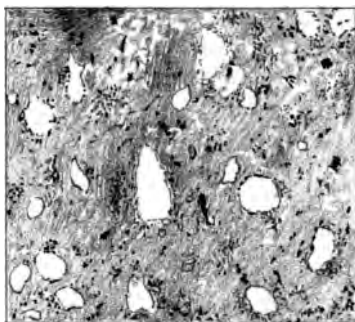


Fig 2.

MAGNIFIED SECTIONS OF INDURATED SLATE.

Fig 1. *Mag. 3 diams.*
2 25

Forster & Co. Dublin

To illustrate Professor Hull's Paper on Baked Slate.

XVII.—ON A SPECIMEN OF MINERAL BORATE FROM TARAPACA, PERU. By J. EMERSON REYNOLDS, Ph. D., F.C.S., Professor of Chemistry in the University of Dublin.

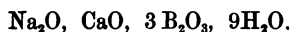
THROUGH the kindness of the Rev. Dr. Haughton, F. R. S., I have had the opportunity of examining two specimens of supposed mineral borates from the province of Tarapaca, Peru. One of the specimens proved on analysis to chiefly consist of nitrate of sodium, with chloride of sodium, and a little sodium and calcium borate as impurities. The second specimen was submitted to a minute examination, the results of which are stated below; and the conclusion at which I have arrived respecting it is, that the mass analysed is a mixture of common salt with a hydrous calcium and sodium borate, which latter differs essentially in composition from any similar compound hitherto described, so far as I am aware. I therefore venture to lay a short account of my examination of this mixture before the Society. The mass consists of long, thin, interlaced fibres, which are white in colour, and possess a silky lustre. The taste is first saline, and afterwards somewhat alkaline. The mineral is easily fusible, first losing much water on heating. It is partially soluble in water, but quickly dissolved by dilute hydrochloric, and by nitric, acid. The well crystallized portions afforded on analysis:—

Boracic Anhydride	.	.	34.12
Water	.	.	25.91
Calcium Oxide	.	.	8.99
Sodium Oxide	.	.	11.25
Sodium Chloride	.	.	19.31
Sulphuric Acid, Fe_2O_3 , K_2O , &c.	.	.	traces.
<hr/>			
			99.58.

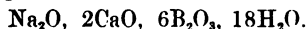
Seven-ninths of the water is removed at a temperature of 300°F .

The common salt can be easily extracted from the substance by means of ice-cold water, and is, therefore, present as a mere impurity. As the analysis showed that this was the only impurity present in sensible quantity, and the only alkaline salt extracted by ice-cold water, I avoided any treatment that might alter the composition of the crystalline base, and determined the percentage of the impurity present. If then, we subtract from the analytical data the weight of common salt found, we evidently get the composition of the pure crystals.

On discussing the numbers in the usual way we obtain the following as the empirical expression for the composition of the mineral:—



The ratios Dana gives for Ulexite are:—

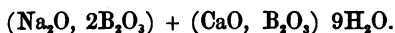


But the analyses from which this expression is deduced are, on the whole, discordant and unsatisfactory; and any formulæ derivable therefrom for the mineral are exceedingly complex; whereas, the mineral I have analysed affords a comparatively simple formula.

If we write ordinary borax thus:—

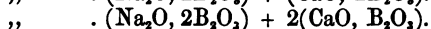
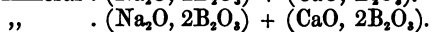
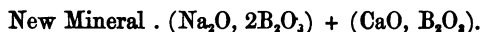


the mineral Dr. Haughton gave me may be written thus:—



In which case we may represent that one of the molecules of water of crystallization in ordinary borax is replaced in the new compound by a molecule of calcium metaborate.

I have no doubt of the accuracy of this formula; but, I hesitate to regard the compound as a new mineral, and to give it a name, until I have had the opportunity of examining some specimens of "Ulexite," which I hope shortly to obtain. Should further investigation confirm Dana's formula for Ulexite, Dr. Haughton's specimen will be the first member of a series, of which Ulexite is, probably, the fourth term. Thus, excluding water from consideration—



The existence of this series of borates has not, apparently, been hitherto suspected; it will, therefore, be a matter of much interest to examine various samples of supposed Ulexite, in the hope of isolating the terms at present wanting.

XVIII.—ON THE TRAP DYKES THAT PENETRATE THE GRANITES, METAMORPHIC SLATES, AND CARBONIFEROUS LIMESTONES, OF THE DISTRICT OF MOURNE, IN THE NORTH-EAST OF IRELAND. By the Rev. SAMUEL HAUGHTON, M.D., Professor of Geology in the University of Dublin.

Read 11th January, 1876.

THE materials of this Paper were collected by me upwards of fifteen years ago, when engaged in completing the exploration of the granites of Mourne and Newry, which I had commenced some years before.

The only portion of my researches, as yet published, will be found in the Journal of the Geological Society of London, 6th February, 1856.

I have there shown that the district contains two granites :

1. Mourne granite.
2. Carlingford granite.

The age of the Mourne granites is unknown, but that of the Carlingford granites is post-carboniferous.

The basic igneous rocks of the district are :

1. Anorthite-Augite syenite, passing into Augite rock.
2. Crystalline massive greenstone, of unknown mineral composition.
3. Fine-grained grey trap rocks, of unknown mineral composition.

Of these rocks, the Anorthite-Augite syenites, and the massive greenstones, are older than the post-carboniferous granites, for they are penetrated by veins of this granite, at Barnavave and at Slieve na Glogh. The age of the fine-grained trap dykes is unknown to me.

I shall now give a brief description of the granitic district in the north-east of Ireland. It consists of three distinct regions.

Firstly, the region known as that of the Mourne mountains proper, which forms a granitic mass isolated from the granites around it, and separated from them by valleys of slate rock : Secondly, the great north-east and south-west granite district, which runs from Slieve Croob, rising 1755 ft. high on the north-east to Slievegullion on the south-west, rising to a height of 1893 ft. : and thirdly, the Carlingford district, running at right angles from Slievegullion to the Carlingford mountains. The granite rocks are surrounded on the north and east by silurian slate rocks, which are highly altered by contact with the granite. A very interesting specimen of this altered slate rock was laid before the Society by Professor Hull during the course of last year. On the south, towards Dundalk and Carlingford, these granite rocks are surrounded by a totally different group of rocks—the well-known carboniferous limestone rocks of the centre and middle portions

of Ireland. All through these three sub-regions I have described, the limestone, granite, and slate rocks are freely penetrated by trap dykes. I prefer calling them trap dykes for the present, because there is considerable doubt as to what their proper name should be.

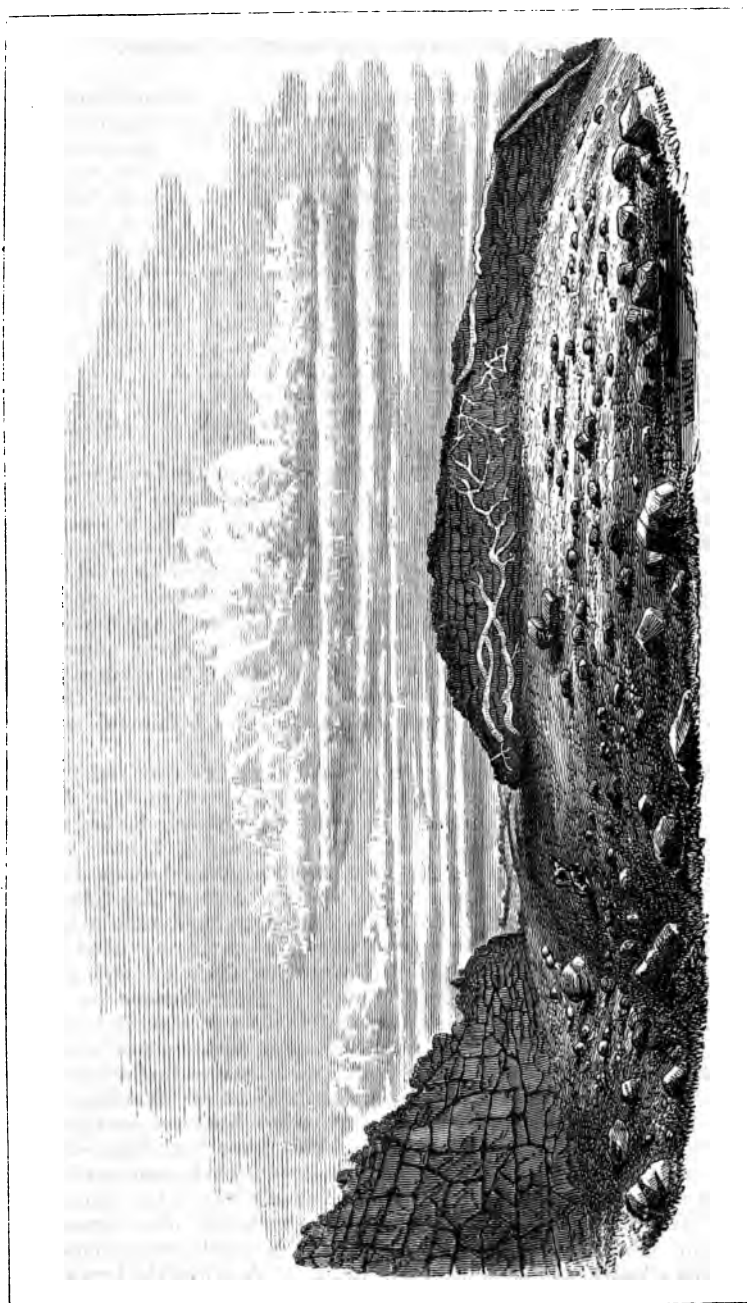
The number of the trap dykes in the Mourne district has always attracted the attention of geological observers. In the map, which was drawn up for a different purpose, we show, between Newry and Slievegullion, a number of red bands in the railway cuttings at Goraghowood, and at Forkill. They each represent separate trap dykes, penetrating the rock, some of considerable thickness, and all presenting a striking and attractive appearance, and at once claiming the attention of the observer. Several of these have been analysed by me, and are described in the present Paper.

The trap dykes penetrate the granites, metamorphic silurian slates, and carboniferous limestones; and they are also found in dykes in the anorthite syenites and crystalline greenstones of the entire country. The distinction between felstones and trap rocks is essentially a chemical distinction, because it is well known you may have rocks totally different from each other in chemical composition presenting the same appearance to the eye of the field observer, and liable to be called the same name; and rocks with the same chemical composition, and which, therefore, must have had the same origin, may (from conditions of cooling and pressure, and other external circumstances which are only local and unimportant) have acquired such different appearances that geologists give them all different names. I, therefore, mean by felstone, or pitchstone, a rock that has little or none of lime or magnesia in its composition, but has a certain percentage of soda or potash instead; whereas in all trap rocks or syenites (I use the term in the broad sense of the German geologists) lime, iron, and magnesia enter into the composition of the rock; while they are absent almost altogether from felstones, pitchstones, and all rocks that approach in their composition to the granites.

Every chemist will recognise at once how wide and broad is the distinction between granitic rocks, whether they be fine-grained or coarse-grained, and these rocks. The difference consists in the removal of potash and soda, and the substitution of lime, magnesia, and iron instead.

The anorthite syenite of Carlingford is a rock resembling the hypersthene syenite of Skye; with the exception that the lime felspar of Skye is labradorite, while the lime felspar of Carlingford is anorthite.

The accompanying sketch shows the intrusion of granite veins into the Carlingford syenite at Barnavave; and those granite veins are associated with syenitic veins, resembling them so closely that it is extremely difficult to distinguish them from each other without chemical aid. The conclusion I have come to from an examination of the district is, that the mass of syenite in the Carlingford district,



Granite veins in Syenite rock, Gap of Barnavave, near Carlingford.

and the granite of the same district, are practically contemporaneous, and that they mutually send veins and dykes penetrating each other. This would make the granite and syenite of that district post-carboniferous, and would make it a younger granite and a younger syenite than our Dublin granites, which are well known to have been formed and consolidated before the carboniferous limestone. I even venture to suppose that the origin of these syenites in the Slievegullion, Flurry Bridge, and Carlingford districts, is a very simple one—that in fact they are simply altered granites. As long as granite penetrates slate rocks it suffers no injury from chemical reactions; but when granite in a pasty condition attacks a mass of limestone rock, it becomes rapidly fluxed, and if it came into contact with a proper quantity of limestone and peroxide of iron, it would be fluxed into a syenite resembling that which constitutes the mass of Carlingford mountain.

Let us now consider the general question of the mineral composition of igneous rocks. This question, some fifteen or sixteen years ago, presented insuperable difficulties, but Mr. Sorby, to whom the geological world owes so much, has given us, by his method of microscopic examination of rocks, an instrument which has enlarged the field of our view. He is enabled to tell us, with a very close degree of approximation by examination of microscopic slices of rocks, what minerals are in these rocks; and when the microscopist tells us what minerals are in the rock, and when the chemist tells us what is the composition of the rock, the microscopist and chemist have a right between them to call on the mathematician to tell how much of each mineral is in the rock.

This is a problem I have recently attempted to solve, and I am glad to say with success, for with the assistance afforded by Mr. Hull's microscopical observations on the lavas of Vesuvius, checked and tested from time to time by special chemical research, I have succeeded in obtaining in each case the most probable mineral composition of the lava—by means of what I shall call the *Law of Least Paste*, which is itself a simple application of the Law of Least Action, which pervades all nature. In turning over this problem in my mind, in connexion with the composition of the lavas, I recollected a saying of the mathematician Poisson, which made a great impression on me when I was a student in Trinity College—"that no problem in nature is indeterminate," and that it only appears so in consequence of our ignorance; that if we knew of the conditions in nature that surround each problem, we would have the means at hand of obtaining an *unique* solution of the problem. Nature never hesitates as to the quantity of the material she employs. She never hesitates, so to speak, as to how much of this and how much of that element shall go to form a mineral, or even a rock-mass. The affinities of the stronger bases settle the ultimate arrangement of the materials of an igneous rock, the substances possessing the highest mineral-forming power being the alkalis, and then magnesia and alumina, while the iron and

lime and silica not appropriated by the minerals are usually left in the paste. The composition of the paste, as arrived at by the mathematical discussion of the analysis of the rock-mass, seems to approach that of bottle glass.

The problem presented to us is to find the *Residual Law*, which shall guide the whole melted mass in arriving at its final composition. The rock-mass consists of a number of imbedded minerals, and a paste which analysis shows to be an inert paste, not possessing crystallising properties. In the whole melted rock the very presence of minerals, forming out of the melted mass, shows the operation of a formative force which must be greater or less in the case of the different minerals; and this formative force, tending to make minerals, will go on, as I conceive it, as long as any chemical affinities in the mass remain unsatisfied. On applying this principle, I found that the indefiniteness entirely disappeared from the equations, and that a single unique result came out. I have applied this principle, in one case, to the trap rocks in the paper before you, and found results similar to those attained in the lavas of Vesuvius.

The trap rocks associated with the granites and metamorphic rocks of Mourne may be best described by taking them from S.W. to N.E. along the axis of the granite, commencing at Slievegullion and Newry, and terminating with Slieve Donard and Ballinahinch.

I. *Massive Syenitic Trap rock, West Base of Slievegullion*, appears to consist of—1. grey quartz; 2. white felspar; 3. greenish black hornblende; 4. black mica.

Chemical Composition.

Silica,	53·28
Alumina,	13·28
Iron peroxide,	10·52*
Lime,	7·42
Magnesia,	4·45
Soda,	3·03
Potash,	2·04
Iron protoxide,	4·08*
Manganese protoxide,	0·80
Water,	1·00

99·90

II. *Massive fine-grained Syenitic Trap rock, half way up Slievegullion*, appears to consist of—1. quartz, inconspicuous; 2. white felspar; 3. hornblende, abundant. The intimate mixture of these latter minerals gives the whole rock the appearance of a crystalline diorite.

* In the following analyses, the iron peroxide is always in excess, and the iron protoxide in defect, as the latter was oxidised in fluxing.

Chemical Composition.

Silica,	57·68
Alumina,	14·44
Iron peroxide,	5·43
Lime,	8·86
Magnesia,	6·20
Soda,	2·41
Potash,	2·41
Iron protoxide,	0·90
Manganese protoxide,	1·20
Water,	0·60
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100·13	

III. *Upper massive Syenitic Trap rock, Slievegullion*.—Crystalline syenite, containing—1. felspar in transparent flat crystals, needle-like, when seen edgewise ($\frac{1}{4}$ in.); 2. hornblende, very minute, disseminated through the mass; 3. Occasional specks and plates of bronze mica.

Chemical Composition.

Silica,	47·60
Alumina,	17·60
Iron peroxide,	9·20
Lime,	12·11
Magnesia,	7·61
Soda,	2·05
Potash,	0·57
Iron protoxide,	2·15
Manganese protoxide,	1·60
Water,	0·44
<hr/>	
100·93	

IV. *Lower Syenitic Trap rock, massive, Slievegullion*.—A grey crystalline trap, consisting of hornblende and acicular crystals of felspar.

Chemical Composition.

Silica,	48·00
Alumina,	15·80
Iron peroxide,	9·80
Lime,	11·78
Magnesia,	9·19
Soda,	1·95
Potash,	0·52
Iron protoxide,	2·00
Manganese protoxide,	1·84
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100·88	

V. *Grey Trap Dyke, in granite, in railway cutting near Wellington Inn.*—A fine-grained trap, grey, with specks of pyrites; consisting of—1. white felspar; 2. green hornblende.

Chemical Composition.

Silica,	50·08
Alumina,	16·64
Iron peroxide,	9·86
Lime,	8·16
Magnesia,	3·72
Soda,	2·93
Potash,	1·15
Iron protoxide,	1·48
Manganese protoxide,	1·04
Iron pyrites,	0·33
Water,	1·04
	<hr/> 96·43

VI. *Dark-coloured grey Trap Dyke, in railway cutting, Wellington Inn (penetrates granite).*—A crystallised trap rock; seems to be composed of hornblendic trap for paste, with hornblende ($\frac{1}{4}$ in.)

Chemical Composition.

Silica,	46·04
Alumina,	18·96
Iron peroxide,	11·56
Lime,	9·64
Magnesia,	7·60
Soda,	2·07
Potash,	0·57
Iron protoxide,	1·87
Manganese protoxide,	0·84
	<hr/> 99·15

VII. *Trap Dyke in slate rock on Carlingford side of Rostrevor Bay, Campbell's Quarry, opposite to Rostrevor Quay.*—A fine-grained greenstone; component minerals not distinguishable; with specks of iron pyrites; and occasionally, nests or cavities lined with green quartz crystals, prase.

Chemical Composition.

Silica,	48·24
Alumina,	14·20
Iron peroxide,	12·64
Lime,	11·89
Magnesia,	7·46
Soda,	1·86
Potash,	0·62
Iron protoxide,	1·87
Manganese protoxide,	1·00
	<hr/> 99·78

VIII.* *Syenite veins in Syenite rock, at Barnavave, near Carlingford.*—A fine-grained syenite, closely resembling the trap dykes penetrating the slate rock at Rostrevor, and the carboniferous limestone at Carlingford.

Chemical Composition.

Silica,	52·80
Alumina,	12·24
Iron peroxide,	17·68
Lime,	5·83
Magnesia,	1·72
Soda,	1·25
Potash,	1·50
Iron protoxide,	2·72
Manganese protoxide,	2·72
Water,	0·80
	<hr/>
	99·26

VIII.* (bis) *Granite veins in Syenite rock, at Barnavave, near Carlingford.*—A fine-grained, cream-coloured, elvan granite, like that found at Grange Irish, at the summit of Slieve na Glogh, and on Slievegullion.

Chemical Composition.

Silica,	68·80
Alumina,	13·20
Iron peroxide,	6·60
Lime,	2·24
Magnesia,	0·71
Soda,	3·81
Potash,	4·29
Iron protoxide,	0·46
Manganese protoxide,	0·88
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	100·99

IX. *Trap Dyke in carboniferous limestone, Carlingford Quarry.*—Fine-grained trap dyke; crystals inconspicuous, with the exception of a few large crystals of felspar.

* The mass of syenite rock, which forms Carlingford mountain, joins the mass of granite near Barnavave, and in this locality the syenitic rock is penetrated by dykes composed sometimes of syenite, and sometimes of granite. [*Ibid* page 93.]

Chemical Composition.

Silica,	49·76
Alumina,	13·68
Iron peroxide,	11·11
Lime,	8·66
Magnesia,	4·14
Soda,	2·80
Potash,	2·31
Iron protoxide,	5·61
Manganese protoxide,	1·04
Water,	1·60

 100·71

X. *Trap Dykes in Syenite rock of Carlingford Mountain. (Slieve Foy).*—Fine-grained, greenish-grey trap rock, with constituent crystals conspicuous. Effervesces slightly with muriatic acid.

Chemical Composition.

Silica,	47·00
Alumina,	14·00
Iron peroxide,	10·01
Lime,	11·56
Magnesia,	7·28
Soda,	2·70
Potash,	0·72
Iron protoxide,	3·75
Manganese protoxide,	1·28
Water,	1·60

 99·90

XI. *Massive Syenite, Rostrevor Quarry.*—Moderately coarse-grained, consisting of pale greenish anorthite, and black metallic augite.

Chemical Composition.

Silica,	48·80
Alumina,	14·40
Iron peroxide,	10·64
Lime,	10·12
Magnesia,	5·06
Soda,	3·06
Potash,	1·66
Iron protoxide,	4·08
Manganese protoxide,	1·20
Water,	1·60

 100·62

XII. *Massive Trap rock, in slate rock, at summit of Slieve Bawn, Rostrevor.*—Greenish grey crystalline doleritic syenite, with thin flat acicular crystal of felspar (anorthite), imbedded in a greenish grey paste.

Chemical Composition.

Silica,	45·72
Alumina,	15·32
Iron peroxide,	11·13
Lime,	11·02
Magnesia,	8·20
Soda,	1·65
Potash,	2·55
Iron protoxide,	2·75
Manganese protoxide,	1·12
Water,	1·20

100·66

XIII. *Trap Dyke, at Woodhouse, Rostrevor; feeds the outburst (XII.), at summit of hill.*—Fine-grained, consisting of felspar (anorthite) and augite, green.

Chemical Composition.

Silica,	45·68
Alumina,	15·80
Iron peroxide,	11·24
Lime,	9·76
Magnesia,	7·08
Soda,	2·07
Potash,	2·43
Iron protoxide,	3·52
Manganese protoxide,	1·04
Water,	2·00

100·62

XIV. *Trap Dyke, in granite, at summit of Little Bingian.*—Fine-grained, with rounded particles and grains of quartz, some of the larger grains containing chlorite in addition to quartz.

Chemical Composition.

Silica,	50·60
Alumina,	14·40
Iron peroxide,	10·20
Lime,	8·65
Magnesia,	5·60
Soda,	2·38
Potash,	2·08
Iron protoxide,	4·13
Manganese protoxide,	0·40
Water,	1·80
	<hr/>
	100·24

XV. *Basaltic Dyke (resembling pitchstone, in granite), at Ballymacilreiny.*—Lithoid basalt, with conchoidal fracture and appearance of lithoid pitchstone; contains occasional large crystals of felspar.

Chemical Composition.

Silica,	52·40
Alumina,	16·24
Iron peroxide,	14·08
Lime,	5·84
Magnesia,	3·28
Soda,	2·70
Potash,	2·07
Iron protoxide,	2·56
Manganese protoxide,	1·20
Water,	0·44
	<hr/>
	100·81

XVI. *Trap Dykes, resembling felstone, in slate rock of Rostrevor mountain.* (Green colour.)

Chemical Composition.

Silica,	61·40
Alumina,	14·40
Iron peroxide,	3·72
Lime,	8·04
Magnesia,	4·88
Soda,	3·51
Potash,	4·29
Iron protoxide,	0·52
Manganese protoxide,	0·80
	<hr/>
	101·56

XVII. *Trap Dyke (resembling felstone), at Armer's Hole, near Newcastle.*—Pale, greenish-grey, semitranslucent trap (resembling felstone); the cleft called Armer's Hole is formed by the disintegration of the dyke.

Chemical Composition.

Silica,	61·84
Alumina,	11·20
Iron peroxide,	7·83
Lime,	8·66
Magnesia,	3·00
Soda,	1·71
Potash,	2·94
Iron protoxide,	0·97
Manganese protoxide,	0·80
Water,	1·20
	<hr/>
	100·15

I was unable to determine the chemical composition of the constituent minerals, except in the case of the felspar and augite of the crystalline syenite which forms the mass of Carlingford mountain. These minerals proved to be anorthite and augite, with the following composition : *

Carlingford Anorthite.

• Silica,	45·87
Alumina,	34·73
Lime,	17·10
Magnesia,	1·55
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	99·25

Carlingford Augite.

Silica,	50·72
Alumina,	9·36
Lime,	16·96
Magnesia,	2·40
Iron protoxide,	18·61
Loss by ignition,	1·52
	<hr/>
	99·57

In addition to these minerals, magnetite seems to be present in all the syenitic rocks of the entire district.

* Proceedings of the Geological Society of London (6th February, 1856, pp. 196-7).

At Grange Irish, near Carlingford, the granite comes into contact with carboniferous limestone, which it appears to penetrate in dykes, becoming converted into anorthite syenite, having the following composition:—

Granite converted into Syenite, found in Dykes in Carboniferous Limestone, at Grange Irish, near Carlingford.

Silica,	47·52
Alumina,	28·56
Lime,	15·44
Magnesia,	1·48
Iron protoxide,*	7·23
	<hr/>
	100·23

Assuming this dyke to be composed of anorthite (x), and augite (y), the most probable composition is derived from the equations

(1) *Alumina equation* :

$$2856 = 34·7x + 9·4y.$$

(2) *Magnesia equation* :

$$148 = 1·6x + 2·4y.$$

From these equations we find

Mineralogical Composition of Dyke.

Anorthite (x),	80·2
Augite (y),	7·9
Paste,	11·9
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	100·0

Chemical Composition of Paste.

	Observed.	Calculated.	Paste.
Silica,	47·52	40·81	+ 6·71
Alumina,	28·56	2·856	0·00
Lime,	15·44	15·04	+ 0·40
Magnesia,	1·48	1·48	0·00
Iron protoxide,	7·23	1·47	+ 7·56

* If the granite veins be altered into anorthite and augite syenite, they must obtain the iron from some source distinct from either the granite or the limestone.

It is not possible to say how much of the iron of the paste is present as magnetite, in consequence of the imperfect chemical determination of the relative proportions of peroxide and protoxide; but if no part of the iron assume the form of magnetite, the paste will have the following composition :

Percentage Composition of Paste in Syenite Dykes in Carboniferous Limestone at Grange Irish, near Carlingford.

Silica,	52.0 per cent.
Lime,	3.3
Iron protoxide,	44.7
	<hr/>
	100.0
Si O ₂	0.867
Ca O	0.059
Fe O	0.621
	} 0.680.

XIX.—ANNIVERSARY ADDRESS DELIVERED BEFORE THE ROYAL GEOLOGICAL SOCIETY OF IRELAND, by the President, SIR ROBERT KANE, LL.D., M.R.I.A.

[Read 9th February, 1876.]

GENTLEMEN :—The period which has elapsed since our last Anniversary Meeting has been marked by a sensible improvement in the condition of the Society, not only as regards the number of our members, and of the papers contributed to our proceedings ; but also by the display of greater activity in scientific research, and of enlarged sympathy with the results, upon the part of those who, from their professional pursuits, or from cultivated taste, occupy themselves with those branches of science for whose study this Society has been founded. For this useful and creditable progress, we are, in my opinion, mainly indebted to the advice so urgently given, and to the example so worthily shown, by my esteemed friend, our late President, Professor Hull ; who, in his eloquent address, when retiring from the position he had so successfully occupied, summarized the *desiderata* of geological inquiry, which he thought might be most usefully taken in hands, and animating his fellow-labourers with that breath of vital intellectual energy by which he was himself inspired, stimulated them to those exertions to which we owe the progress which this Society has recently made. I cannot pretend, that in addressing you this evening, my words should have such weight, as naturally belonged to the suggestions of one whose well-earned position in geological science conferred

rather than derived authority from the Presidential chair. I feel that my relations with geology, and with this Society, are of a much more humble type; that I take part in your proceedings more as a learner than as a teacher; that my place is rather with those who glean in the paths of the pioneers of science, than with those leaders by whose original conceptions new paths of inquiry are opened out. Having devoted myself during my own period of scientific activity, almost exclusively to those branches of physical and chemical inquiry, whose bearings upon geology were but collateral and indistinct, in the then existing state of science, it has been to me of great interest to observe the growth of a more intimate and better grounded connexion, between those branches of learning where the laws of phenomena and the methods of inquiry, which have been so fruitful of discovery in the fields of chemistry and physics, may be rendered available as aids to the solution of those great questions of geological origin or transformation; and that those vast and complicated changes which involve for their completion magnitudes in time, in space, and energy, transcending all human imagination, may yet, when, as it were, seized in their inception, and examined, as it were, in their microscopic anatomy, their molecular actions, and in their minutest parts, be made intelligible, and their nature clearly indicated by the careful and cautious application of the light afforded to their study, by the principles and processes of physical and chemical science. There may thus be obtained for the use of the philosophical geologist, a means of accurate investigation of many difficult questions, now vainly waiting for solution, and which may afford to the phenomena of Plutonic and metamorphic geology, such guiding light as the application of zoology and botany supplied, for establishing the philosophical relations of the stratified rocks. That I am not singular or over sanguine in expressing such anticipations is evident, not merely from the observations of Professor Hull, in his last address, but also from the researches which he and others of our members have undertaken in that direction, and to which I shall have to recur elsewhere. Before proceeding further, however, with any such considerations of merely theoretic interest, it is my duty to notice briefly the papers, which, during the past twelve months, have been submitted to the Society, and which have formed the substance of our proceedings. In doing so, I shall not take them exactly in the order in which they were read, but shall arrange them in some groups, which, as it appears to me, will better exemplify the natural connexion of their subject-matter, and of the methods employed in such enquiries.

For an important portion of our proceedings, the Society is naturally indebted to the active exertions of the director and the officers of the Geological Survey of Ireland, whose observations made in carrying out their great work are usually communicated to this Society, and constitute, as might be expected, material for our meetings of great interest, practical and theoretic. Of such papers, I would mention that by Mr. G. S. Kinahan, on "The Denudation of the Valley of the River Slaney, along the line of fault, and the formation of its estuary

out of the drift, principally during the period of the 25 feet beach." The author has traced the history of various alternations of elevation and subsidence which that district has undergone, and concludes that the present position of that estuary has been due rather to marine than to fluvial action.

Our excellent Secretary, Rev. Mr. Close, directed attention to the bendings over, near the surface, of highly inclined strata; and in reference to examples occurring at Lismore and elsewhere, he discussed the question, as to how far the gravitating action of a hill side, or the driving of an ice sheet, could better explain the phenomena. In Lismore, he considers the weight of the hill to have acted, as the main direction of the ice was opposite; and the slope of the hill being very slight, it serves to show the great force which may be exerted, when long continued, under even a very small angle. Similar considerations have presented themselves in regard to the eocene beds, in the north-east side of the Isle of Wight, to our distinguished Treasurer, Rev. Dr. Haughton, who gave us an account of an excursion made by him to that interesting island, and described the remarkable position of the *Poseidomyas*, which, in the nearly vertical beds, are relatively, to the matrix, nearly in the original position of boring down through the mud, as also the shattered condition of the flints on the shores of Alum bay, which show that they were subject to great strains while in the chalk strata. The learned author considers, therefore, that the violent folding of those beds was effected by a somewhat sharp and severe thrust, with horizontal compression, which he regards as having been contemporaneous with the folding of the same formations in the Pyrenees on different anticlinals.

The question of the occurrence of true upper boulder clay in Ireland has been well discussed by the officers of the Geological Survey. Mr. Hardman, who has brought the subject before this Society, is of opinion that it is unquestionably to be found in various places in Tyrone, Queen's County, Carlow, and Kilkenny, in all which districts he describes localities and gives sections illustrating his views. In regard to some of those, and especially as to Archer's Grove, Kilkenny, Mr. Hardman's observations have been confirmed by those of Professor Hull.

The evidences remaining over the surface of this island, of the former existence of extensive glacial action, have been the subject of several communications, especially in relation to the distribution of the great gravel or Esker deposits by the tides or currents of the glacial seas. Mr. G. H. Kinahan called attention to an outlier of glacialoid, or rearranged glacial drift, at Knockree, one of the Mourne hills, which had been mistaken for a portion of the upper boulder clay already alluded to; and Dr. Macalister communicated observations on the glaciation of West Argyleshire, which help, in an important degree, to illustrate peculiarities in the phenomena of glaciation in the north-east of Ireland, the nature of which has been discussed by Dr. Macalister, and by Professor Hull.

To our ex-President we are indebted for an interesting paper on the metamorphosis which the Carboniferous limestone at Haulbowline, Co. Cork, has undergone, its bedding being almost obliterated, and a N. and S. jointage substituted instead. These beds had undergone the crumpling-up for which they are remarkable, before being thus metamorphosed; and the change of mineral character, having been effected by tranquil percolation of strongly charged calcareous waters, had given origin to the varied characters of marbles of which we have seen such beautiful examples. The process appears to have been completed prior to the deposition of the upper trias beds.

Other not quite analogous examples of metamorphism of the Carboniferous limestones have been observed, especially in the quarries at Skerries, by our colleague, Dr. Frazer. The replacement appears to have been principally by carbonates of iron and manganese, which, by subsequent oxidation, produced ochreous nodules filling cavities in the limestone, and spreading within its beds.

The next class of papers to which I have to direct attention, and which I consider most valuable contributions to our proceedings, are those in which the assistance of chemistry, mineralogy, optics, and mathematics, has been brought to bear upon the solution of important questions of the origin, constitution, and metamorphism of rocks. For these we are, as in so many other respects, principally indebted to Professor Hull, and to our Treasurer, Rev. Dr. Haughton, who, applying to those complicated problems the many-sided lights of his varied and brilliant intelligence, has not merely himself shown what valuable results can be obtained by applying those aids of collateral science to geological inquiry, but has been most usefully influential in aiding and directing the researches of others of our fellow-labourers in the same, or in similar, fields.

An example of this scientific study of metamorphism may be found in Professor Hull's paper on the microscopic study of the indurated slate, from Claremont Hill, near Dundalk. This slate is baked and altered by the heat of the adjacent traps. It has a matrix paste, a translucent glass containing unaltered grains of silica, and was analysed by Dr. Haughton. It was found to contain large proportions of alkalies and lime; it was, therefore, comparatively easily altered at a temperature below 3000° Cent., and its vitrification appears to have been accompanied by the separation of its principal iron element, under the form of magnetite, in distinct crystalline grains.

The neighbouring locality of Mourne has also given origin to an important paper of this class, that by Rev. Dr. Haughton, on the trap dykes of the Mourne district, of which sufficient has been already laid before the Society, to show the interest it will present when its fully-developed methods and results shall be brought forward by its learned author. In the portions already read (omitting for the present the chemical and microscopical details), Dr. Haughton describes the three great divisions of the Mourne granites:—1st, the Mourne Mountains proper; 2nd, the Slieve Croob and Newry axis;

and 3rd, the Carlingford district, and especially the masses and dykes of syenite from Slieve Gullion to Carlingford. These syenites and granites are practically contemporaneous, as each sends veins into the other, and into the carboniferous limestone, in various places between Dundalk and Carlingford. Dr. Haughton believes these syenites to have been formed from granite, by the introduction of lime and magnesia from the carboniferous limestone, and of iron from elsewhere, as he has followed such veins from the granite into the limestone, and found that they have changed their composition within their new matrix. The syenite, he concludes, is thus the granite altered by the limestone, the alkalis of the granite having been removed, and replaced by lime, magnesia, and iron. Dr. Haughton naturally explains that chemical analysis alone is quite insufficient for determining the mineralogical composition of such rocks, on account of the paste which, being of indeterminate constitution, renders the whole problem vague. To remove this vagueness the microscope lends its aid, and revealing the presence or absence of certain crystalline minerals, gives a numerical ground on which the mathematician may operate, and by means of a form of indeterminate analysis, arrive at the maximum and minimum limits of the quantities in which, under the given circumstances, these minerals can be formed. With a subject presenting such great and varied scientific interest, and in hands which can lend, even to the dreariest of subjects, a popular and exciting interest, it can be understood, that the continuation of Dr. Haughton's paper, and the discussion of its details will yet probably afford to the Society more than one evening of intellectual enjoyment.

In addition to those proceedings of more specially geological importance, we have to thank several of our members for notices of chemical and mineralogical interest, which, however, are by no means destitute of a geological bearing. Thus, our colleague and secretary, Dr. Reynolds, whose recent elevation to the University Chair of Chemistry has been hailed with so much approval, as the meet reward of his scientific merits, has taken advantage of the abundant development of beryls in the granites of Donegal, to prepare and to exhibit to us in large quantities the earth glucina, hitherto known only on the small scale, and will thus be in a position to determine, by a complete study of its compounds, whether it belongs to the magnesian or to the aluminum group, and what is its exact equivalent number, and its specific heat, questions which still remain undecided. Dr. Reynolds has also analysed and exhibited a new variety of boracite; and Dr. Frazer, the arsenio-phosphates of lead, associated with lead ores in Wicklow. Mr. Tichborne has also supplied some useful chemical notes, especially in reference to the extensive diffusion of fluorine in rocks and minerals, a subject which, taken in connexion with the association of fluorine with phosphorus, and of both with organic beings, is worthy of further careful observation.

This research of phosphoric acid in the metamorphic and Plutonic rocks becomes specially of interest, as it may afford an indication of

the extent to which these mineral masses, in their original formation, included organic remains, which, by the subsequent processes to which they have been subjected, have lost all proper form, and exist only as mineral elements in newer combinations. It is thus that certain lower silurian and Cambrian beds, destitute of fossils, yet give on analysis such traces of phosphorus as point out their original formation to have been in seas rich in organic life; and even in such accumulation as in some of the Bala beds, may furnish deposits of phosphatic nodules of great commercial value. These observations are specially of interest to us in Ireland, where, owing to the rareness of those newer formations which furnish the valuable coprolite beds of Cambridge and Suffolk, such sources of agricultural wealth are absent; but where, the older Cambrian and silurian strata being so largely developed, we may have a field for discovery of accumulated remains of early organic life, which may become the sources of industrial activity.

We owe to our distinguished Treasurer, Rev. Dr. Haughton, a paper on a subject of Physical Geography, of great popular as well as of scientific interest, that of the tides of the American Arctic Archipelago, and their influence on Polar expeditions. The writer describes, with his usual lucidity of style, the entrance of the tide wave into the Arctic Polar basin, by the three channels:—1, Behring's Strait; 2, Davis Strait; 3, the Greenland and Barents Seas. Of this third wave little is known. The first he considers a simple lunar semi-diurnal tide; the second is complex, consisting of lunar and solar semi-diurnal, and lunar and solar diurnal, tides. These two sets of tides must meet, as the author considers, in MacLure's Strait, and at the line of meeting there is still water, and, consequently, undisturbed block ice, most probably impassable for ships. He further considers that if—as is not unlikely—the Behring's Strait wave meets the united Atlantic waves to the north of Greenland, and on this side of the pole, sledges will be more likely than ships to reach the pole. Every element of information on this subject has an almost painful interest, as connected with the dangers surrounding the undaunted explorers of those ice-bound seas, who now, midst the sunless desolation of the Arctic winter, seek at the peril of their lives to solve those problems of scientific geography, which we in the comfort of our homes discuss at ease. Let us look forward to their safe and glorious return, with success achieved, to their country and to their friends.

I have thus briefly and imperfectly described the various labours which have occupied the Society during the past year, as regards the papers read, and other communications made to our meetings. But the labours of our members have extended over even a wider field, but still so connected with our own immediate work, that it would be improper to leave it entirely without notice. The more abundant means possessed by the Royal Irish Academy, for the publication of memoirs which, by extent of matter or richness of illustration, should be too costly for the resources of this Society, have enabled many of our members to arrange for publishing important and elaborate me-

moirs on geological subjects, in the Transactions of that institution. In this, the two bodies do not in any way interfere. The researches are equally, in substance or in abstract, also laid before us here, and supply valuable material to our discussions; and it is most desirable that in this way, with judicious husbanding of our resources, the two cognate national institutions may proceed thus hand in hand, in promoting the cultivation, and honouring the cultivators, of geological science. Of the important memoirs which have been thus laid before the Royal Irish Academy by our members, and have been printed by that body, I may mention, among others, the elaborate researches of Professor Hull, and of Rev. Dr. Haughton, on the "Mineralogical and Chemical Constitution of the Lavas of Vesuvius," a work which, in regard to the labour which it required, the varied knowledge which its execution involved, and the important bearing of its results upon the theory of the formation of igneous rocks, may be expected, when complete, to constitute one of the most valuable contributions which have recently been made to the literature of geological science.

In bringing these observations to a close, it would be neglectful were I not to make some remark upon the loss which geology had sustained, just at the opening of our year, by the death of Sir Charles Lyell. I shall not attempt to bring before you any review of the labours of that eminent man. It would be but an impertinence in me, in presence of many who were his associates in geological inquiry, to attempt what I could only dwarf by my insufficient execution. I omit, therefore, all such review, the more that, just at this time, from the presidential chair of the London Geological Society, with which Sir Charles Lyell had been through life so closely identified, there is certain to proceed a description of his life and works suited to the occasion, and worthy of the man, and of his place in the history of science. I shall only make one remark, which is,—that I regard the great distinction of Sir Charles Lyell, and the main cause of the great influence which he exercised on the progress of geology, to have had its source, in the completeness and many-sidedness of his mental and scientific character. He was not, by any means, merely a geologist; he was not even exclusively a man of science. Born under circumstances highly favourable to his intellectual and social culture; the son of one, himself a scholar and a man of science of no mean rank, Sir Charles Lyell prosecuted with equal ardour, and with similar success, the pursuits of literature and of science, combining, amidst the glorious scenery of Italy and Sicily, the studies of the classical, with the researches of the geological, inquirer. It was by this wide and generous sympathy with art, with antiquity, and with nature, that he was freed from the thralldom and narrowness of preconceived doctrines and theories, that he was enabled to look at phenomena as they were, and measure them by their proper standard; that, from the ever shifting levels of the Mediterranean shores, he was enabled to infer what had taken place, in ages back, from what he saw taking place before his eyes; and, bringing into geological account

the scientific and sure philosophy of close induction, he was enabled to establish, upon a firm basis, the real influence of existing causes of geological change, and thereby to lay the foundation of what now constitutes the Philosophy of Geology. Such is my view of Sir Charles Lyell, and I trust that we shall always possess among our leaders in science men like him, equally examples of what is worthy of respect in the scholar, the philosopher, and the man.

I thank you, gentlemen, for the indulgence with which you have heard what to many here must have appeared but the dull iteration of those topics, which already they had heard more fully and more forcibly discussed on other occasions. It is, however, by bringing together and co-ordinating the work which has been done by our members during the past session, that we are able to fully appreciate the value of what has been accomplished, to recognize how much remains still to be done, and to judge in what fields the exertions of our workers may be most profitably employed. If I have done, as I certainly wished to do, justice to those who have sustained the reputation of the Society during the past year, and given, in any sensible degree, guidance and encouragement to those to whom we may look for our future progress, I shall have attained the object which I had in view, and I shall esteem myself happy in being again favoured with the opportunity of presiding at your meetings.

XX.—NOTES ON THE STRUCTURE OF HAULBOWLINE ISLAND, CORK HARBOUR AND ON THE GEOLOGICAL AGE OF THE FLEXURES OF THE STRATA IN THE S. W. OF IRELAND. By PROFESSOR EDWARD HULL, M.A., F. R. S., Director of the Geological Survey of Ireland.

[Read 8th December, 1875.]

HAVING recently visited the Island of Haulbowline, in Cork Harbour, accompanied by Mr. Kinahan, of the Geological Survey, for the purpose of reporting to the Admiralty on the practicability of obtaining fresh water by means of an artesian well, I made some observations on the structure of the Carboniferous limestone there, which may not be without interest to the Fellows of this Society.

The island lies opposite the mouth of the River Lee, where it enters Cork Harbour; and the main channel, less than a quarter of a mile in width, and with a depth of five fathoms at low tide, lies between Black Point, on the north coast, and the cliffs of limestone, which plunge into the water along the north-west margin of the island. From these cliffs the ground slopes downwards towards the east, and the limestone rock becomes covered up by boulder clay and gravel, which stretches eastward under the water into the long spit, due to the position of Spike Island. The Admiralty are now constructing graving docks of the largest size at the island, in doing which they avail themselves of the forced labour of the convicts of Spike Island.

The limestone of Haulbowline is described in the *Memoirs of the Geological Survey** as composed of thick-bedded grey limestone, traversed by numerous joints, as well as by fissures and cleavage planes, which prevented any determination regarding the original stratification. Since that time, however, the rock has been opened out in a quarry, which yields large blocks for the construction of the docks, and better opportunities are thus afforded for observing its characters. On referring to the Geological Survey map (sheet 195), or to the map of Sir R. Griffith, it will be seen that the limestone of the island lies close to the axis of a sharp synclinal fold, which runs in a direction about E. 10° N., and W. 10° S.; as the base of the limestone, with the underlying Carboniferous slate, appears on the north shore of the channel, near White Point, with a southerly dip, and again at Spike Island, with a northerly dip. North of the island, the boundary between the slates and the limestone must run along the centre of the channel, and is concealed from view.

As regards the limestone of the island, it was clear, upon close inspection, that it has undergone great changes since the period of its formation, and even subsequent to the production of the foldings and tortions to which, along with all the rocks of the district, it has been subjected. The bedding is almost entirely obliterated, and we were only able to observe true stratification in one spot, in which the rock was rather shaley; here the dip was southerly, at 75° . In the next place, with the exception of some crinoid stems, nearly all traces of fossils have been obliterated. This has been confirmed by the microscopic examination of a thin slice, kindly made for me by Mr. Howard Grubb, which consists of carbonate of lime, either in an amorphous or crystalline state, but without any trace of organic structure. Now it is impossible to doubt that originally the rock was made up of calcareous shells, or skeletons of marine forms of life, and their absence is a sufficient proof to my mind, that the rock has undergone a change of condition, or transformation, since it was originally deposited. In addition to this, it is penetrated by veins of calcite, interlacing and ramifying about in all directions. Sometimes, also, the calcite has been stained red by iron oxide, in blotches and strings; and owing to these accidents of transmutation, the stone, when polished, produces a very handsome marble.† The whole of the phenomena above described combine to show, that the limestone of Haulbowline has been completely replaced by carbonate of lime, in a crystalline or amorphous state, through the agency of waters charged with carbonic acid permeating the whole of the mass, and alternately dissolving out, and again precipitating from a state of solution, the same mineral in a new form.

* Explanation to accompany sheets 187, &c., of the Survey maps, p. 52.

† Specimens of the marble, presented to the author by Mr. Charles Andrews, Superintendent of the works in Haulbowline, were exhibited at the meeting of the Society, and have been presented to the Royal Dublin Society.

Now, it must, as I think, be clear, that there have been two successive stages of this transformation, as the white calcite veins are later than the dark grey amorphous mass through which they ramify; while the formation of the amorphous mass itself is of later date than the flexures or crumplings of the rock, which are obliterated. Nor is it improbable, that if the rock had remained in its original nearly horizontal position, as it does over large tracts of the central plains, little alteration in its organic structure would have taken place. In the neighbourhood of the Haulbowline limestone, the crushing force exerted on the limestone must have been excessive, while at the same time it would have been thrust downwards along the axis of the trough, relatively to the position of the anticlinal arches simultaneously produced.

In such a position, occupying the bottom of a narrow trough, underlain by nearly impermeable shales or slates, and traversed by joints and fissures produced during the period of the terrestrial movements, the rock would be in a state highly favourable to the action of water charged with carbonic acid, which, in process of time, would appear to have completely transformed the original rock.

At some subsequent period, the white calcite veins were infiltrated amongst cracks and fissures arising from fresh terrestrial movements, while the red iron oxide was the last of the deposits.

The manner in which the highly flexured strata of this part of Ireland have received their present surface form of parallel ridges and valleys, has been admirably elucidated by the late Professor Jukes, in his paper on "The Origin of the River-Valleys of the South of Ireland;,"* while Professor Harkness has shown how the limestones are (when pure) traversed by systems of jointage, which seem to depend partly on the crystalline form of calcite, and to have been brought about by mechanical forces, subsequently to the consolidation of the rock itself.† He also remarks upon the frequent obliteration of the planes of bedding in the limestone, and their replacement by parallel systems of cleavage or jointage, traversing the beds in a direction at right angles to the strike. These observations harmonize with those here pointed out as affecting the limestone of Haulbowline.

But the question still remains, at what geological period were these strata crumpled and folded along the numerous approximately eastward lines of flexure? In the south of Ireland there is manifestly no means of answering this question, as the Carboniferous beds do not come in contact with any formations newer than themselves. We are, therefore, obliged to have recourse to analogy with other districts; and on comparing the lines of disturbance which have influenced the Carboniferous and Devonian rocks of the south-west of England, and Wales, with those of the south of Ireland, and observing their identity

* Quart. Jour. Geol. Soc. Lond., vol. xviii.

† Ibid., vol. xv.

in direction, and similarity in intensity, we can scarcely hesitate to assign them both to the same geological period.

That this period is older than that of the Upper Trias or Keuper, is clear from the almost horizontal position in which the strata of this age rest on the disturbed and denuded edges of the Carboniferous rocks, around the Somersetshire and S. Wales coalfields, and along the flanks of the Mendips; but throughout this part of Britain the Permian formation is entirely unrepresented, and we are still left in uncertainty whether the disturbances took place before or after the Permian period.

In order to find an answer to this question, it is necessary again to appeal to analogy, and refer to other districts in Britain where the Permian rocks are in contact with those of Carboniferous age, and so we look to the north of England, and find in the districts of Lancashire and Yorkshire the data we are in search of.

Now, in this part of the country, it has been shown by the late Professor Phillips,* and by the officers of the Geological Survey,† that the Carboniferous strata are bent into numerous folds, sometimes not very sharp, but all nearly parallel, and ranging in directions similar to those of the S.W. of Ireland, and of the S.W. of England, and Wales. And as parallelism of direction may be assumed (in accordance with the views of Von Buch) to be evidence of identity as regards the age of such flexures, we may conclude without much hesitation, that the disturbances of the Carboniferous strata of the south of England and Ireland are of the same age as those of the north.

Now, the position of the Permian beds in the north of England—resting as they do on the denuded surfaces of these Carboniferous beds—clearly proves that the disturbances and denudation of the latter took place before the Permian period had set in. It is on this account that in Lancashire, Yorkshire, and Durham, we find Permian beds resting on successive members of the Carboniferous series, from the coal-measures and millstone grit down to the mountain limestone, in which case the denudation has been to the extent of thousands of feet of strata.

From all this, I conclude that the Carboniferous and Devonian rocks of the south of England and Ireland were bent and folded along the main lines of flexure which are so remarkable and persistent immediately upon the close of the Carboniferous period, and before any beds of Permian age were deposited.

Upon the formation of these great flexures in the south of Ireland, which must have resulted in the production of high ridges and deep parallel valleys, sloping off into a more level plain towards the north, and exposed to the agencies of denudation, that system of drainage set in, which, after the manner described so well by Mr. Jukes, ultimately resulted in the formation of the present features of the country.

* Geology of Yorkshire.

† Hull, "On the relative ages of the leading Physical Features and Lines of Elevation of Lancashire and Yorkshire."—*Quart. Jour. Geol. Soc. Lond.*, vol. xxiv., p. 323.

XXI.—IRISH DRIFT. SUB-GROUP—METEORIC DRIFT. G. H. KINAHAN, M.R.I.A.

[Read April 12, 1876.]

IN Ireland a considerable portion of the drift must be *glacial*, or ice-formed, as it is similar to the ice-formed drift accumulating in other countries at the present day; a second group is *aqueous*, or water-formed; and a third *meteoric*. In the study of the drift phenomena of the country, those belonging to the third group are usually ignored; yet they are of considerable importance. In this communication it is proposed to direct the attention of the Society to the meteoric drift.

Meteoric drift may have its origin from the combined effects of two or more of the subaerial agents, or the accumulations may be almost entirely due to wind action. It is known that if a country is devoid of a protecting envelope of vegetation, its surface is more subjected to meteoric abrasion than under other circumstances.

This can be studied to a small extent at home. If land is in tillage, the surface soil is invariably carried from higher to lower ground, so that if a field slopes very much, farmers are compelled to cart the soil up again; otherwise the low portion will have a deep soil, while the high portion will have scarcely any. Meteoric denudation, however, is more striking on a hill-side, where a cart-track or drain made in the summer will often be considerably widened and deepened during the winter, tons of *detritus* being carried down to be lodged on some piece of more level ground.* We can also study this action in railway or other cuttings and embankments, if the slopes are left for any time unsoiled; also in such a place as the neighbourhood of Swansea, where the fumes from the smelting furnaces have destroyed the protecting coat of vegetation; while abroad Agassiz has drawn attention to the vast quantities of meteoric drift found in Brazil; and other observers have recorded similar action in India, Abyssinia, and elsewhere.

The *debris* due to the different agents classed as meteoric denudants is carried from higher ground by wind and water to lower levels, where it accumulates, the mass varying in thickness according to the length of time the wasting surface is unprotected; also being greatest in low land adjacent to hills. In Ireland, as the former ice covering gradually retreated, the surface of the ground must have been left unprotected; also after the retreat of the Esker sea (350 feet beach); and, but to a much less degree, after the retreat of the seas that have left marginal lines at about the 100-feet and 25-feet contour lines of the Ordnance Survey. This suggestion is borne out by the facts observed, as in many places, particularly in south and south-west Ireland, there are drifts evidently neither glacial

* In the Killaloe district such a stream, "in three or four days of heavy rain," carried down with it *detritus* that covered about an acre of meadow land, on an average three inches deep.—*Memoir Irish Branch Geological Survey, Ex. Sheet cxxxiii.*, p. 33.

nor aqueous that extend over vast tracts, ranging from a few inches in thickness on high ground to many feet on the low lands. This drift when formed from the weathering of shales or slates, as in the south of Ireland, is for the most part, an angular, gravelly drift, while the weathering of sandstones forms fine sands. In the county of Limerick the weathering of the dolerites and eurytes forms a rich, yellowish, deep soil, in places, over the "limestone gravel" of the country. The weathering of the other different kinds of rocks forms local varieties of meteoric drift not necessary to enumerate. We may, therefore, pass on to the weathering of older drifts.

Meteoric drift, formed by weathering from older drifts is often more or less confusing, and has led to classifications of the drift that will not bear careful investigation. Re-arranged glacial drift (*glacialoid drift*) may be very similar to the original glacial drift from which it has been formed, and careless observers may easily mistake the former for the latter. Usually, when an old drift, whether clayey or gravelly, weathers, the materials are more or less sorted, the clayey and sandy particles separating, while the coarser materials are congregated together. This is especially the case when the weathering takes place on a steep slope, the larger fragments rolling down, while the smaller particles are carried away by water or wind. If the weathered drift is glacial, the re-arranged meteoric drift will contain innumerable glaciated fragments, as their carriage from higher to lower ground could not obliterate the striæ, and in many cases not even the glacial etchings and polishing. In many cases a little examination will show that such supposed glacial drifts graduate into, and are part of, a series of stratified drifts; or their position is such that they overlie accumulations whose age is long subsequent to the Glacial Period.*

Some meteoric drifts are due to the weathering of cliffs, which in places may be caused by the denudants, water and the atmosphere combined; such as, the weathering of a cliff margining a lake or a sea. Such a cliff must form and weather as often as the water is stationary for a time at any levels (a , a' , and a'' , Fig. 1.), whether the water be rising or falling; and in either case the denudations will be due to the waves of the water undermining the cliff, while meteoric action loosens the upper mass, and accelerates its fall. The drift formed by this weathering, especially if the water is falling, will in great measure be similar to the

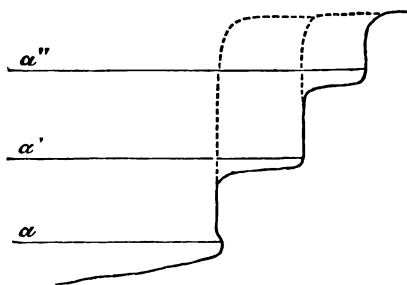


Fig. 1.

* Some glacialists contend that every drift in which any glaciated fragments are found must be glacial; the fallacy of this, however, ought to be apparent.

original drift, whether glacial, aqueous, or older meteoric drift, as the materials contained in the masses forming the slips may often be left nearly, if not quite, undisturbed. This action may be seen going on at innumerable places on our coast, and at the margin of lakes. Other re-arranged drifts are solely due to meteoric action on cliffs, in which case the newer drift must also be very similar to that from which it has been formed. These meteoric slopes of *detritus* lead to erroneous conclusions, for in many places they constitute due masses of a re-arranged ancient drift lying on a newer. This seems to be a very important point in the consideration of the drift phenomena. Therefore it may be allowable to place on record some localities in which, either naturally or artificially, apparently ancient drifts now lie on quite recent accumulations.

On the west coast of Galway and Mayo, in places between Mannin and Clew Bays, there are large slips in the cliffs of glacialoid drift which cover up a greater or less quantity of the recently formed beach. Among the west Galway hills, in places, there have been slips in the drift slopes—masses sliding down into the valleys and covering up the recently formed fluviatile drift; and similar slips may be seen among the Tipperary hills.

In Wexford harbour there were drift cliffs margining the north intake from the sea. These in many places have been since changed, either naturally or artificially, into slopes; but in either case more or less of the re-arranged ancient drift now lies on the recent estuarine accumulation. On the coast between Wexford and Arklow the sea is generally margined by drift-cliffs that are yearly being denuded backwards. In some places, however, the marine denudation has ceased for many years, and meteoric abrasion has changed the former cliffs into slopes, the re-arranged ancient drift now extending outwards from twenty to one hundred and fifteen feet over the recent sea-beach. In one section, exposed by a stream across such a slope, in the townland of Tinnaberna, there is a depth of nearly twenty feet of a drift, similar in aspect to the drift of the adjoining country, on the recent shingle and gravel. Somewhat similar cliff-weathering has taken place near Cullenstown, on the south coast of Wexford, where a cliff of glacial drift has weathered, and its *debris* covers up part of the recent beach, for a considerable depth and width.

Also on the south coast of Wexford, and a little west of the last locality, there seems to be a post-drift fault, of which Fig. 2. is a diagrammatic sketch: *a* and *a'* being sandy, clayey drifts, containing angular

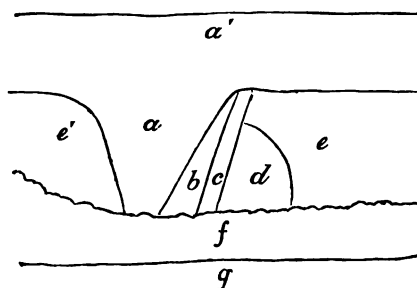


Fig. 2.

fragments and faint lines of deposition; *b*, a substance like calcareous tufa; *c*, a wall of brecciated stuff like fault rock; *d*, a patch of sand near the wall, of a peculiar reddish colour; *e'* and *e*, brecciated, unstratified drift; *f*, a recent bank or talus due to the weathering of the cliff; and *g* the strand. The supposed fault was so peculiar that it was again visited after rough weather, when the sea had cleared away the *debris* from the base of the cliff. Then it was evident that

a and *a'* are very recent meteoric drift; *b*, calcareous stuff that remained in an old limekiln; *c*, brecciated stuff, apparently baked and semifused drift; *d'*, sand altered slightly by the heat of the limekiln; *d*, a pocket of sand in the drift and *e* drift. Although the drift (*a* and *a'*) above the site of the limekiln must be very recent, yet it seems to be identical in aspect with the normal upper drift in the

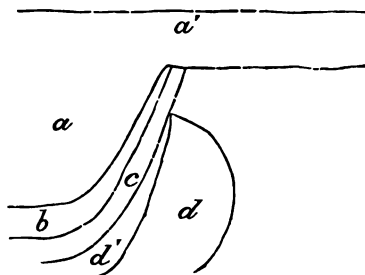


Fig. 3.

cliffs to the west; and this upper drift contains so many glaciated fragments that one geologist said of it, "it must be glacial drift." Here we have a record, not of an older drift on a newer, but of a meteoric drift only a few years old that is identical in aspect with a very ancient drift. In south-west Galway a new course for the Duhallow river was cut, and in one place, after passing through what seemed to be glacial drift, they came on bog containing sticks seemingly cut by man, and the bones of cows and sheep. To this place my attention was directed by Mr. Edward Clibborn. However, on visiting it, it was evident that a cliff of glacial drift, while weathering, had smothered up an old water-course, and covered part of the adjoining bog. A somewhat similar case may be seen in the flat southward of Croaghmoyle, Co. Mayo, where a glacial drift-cliff has slipped, and now, in the stream-section, over ten feet in depth of this drift covers the recent bog. In the Co. Carlow, at the stream from the coom, on the N.N.W. of the summit of Mount Leinster, there is a thick angular drift, which, when traced northward, is found to lie on deep recent bog; the latter still further northward forming a surface accumulation. It is, therefore, quite evident that part of this drift must be very recently-formed meteoric drift; yet it is similar in aspect and composition to the rest of the drift on the hill slope, part of which is under the bog.

At the north end of Killiney strand, Co. Dublin, at the White Rock, a vast quantity of drift, taken from the cutting for the Dublin and Bray Railway, was tilted over into a spoil bank. This beach was subsequently denuded by the sea, and a section exposed (Fig. 4, showing below a drift, like glacial drift (*a*), and above a gravelly drift (*b*). This section is so natural-looking, that, as I believe, an

eminent geologist has described the upper drift as middle or intraglacial gravels; yet no drift was there when I was a boy. Other examples of recent accumulations, that are covered up by masses of older drift, could be mentioned; but enough of examples have been given to show how cautious a geologist ought to be before coming to a definite conclusion.

A sub-variety of the meteoric drift is the *Æolian drift*. With the sand-dunes on our coasts most people are familiar, but few seem to study them, to learn "whence they come or whither they go." As has been suggested in another place,* some of these fine sands seem to have been formed in glaciers, being the grinding from the contained blocks subsequently carried down in the rivers and deposited in lakes or seas. This, however, will not account for the formation of all *Æolian drift*, as some, like those in places on the west coast of Galway, contain more than 70 per cent. of calcareous matter, and are evidently ground-up shells or other calcareous organic substances; while in other places, as on the Wexford coast, the drift or rocks of the country may furnish the material for their origin. In all cases, no matter what their origin, they are brought into their present position and form by wind; on-shore winds during low water, carrying inland the small particles from the sea beach, while the larger are left behind. Afterwards the accumulations are ever-changing, hills being first piled up, then removed; hollows excavated, then filled, and subsequently re-excavated. If we examine sections of this *Æolian drift*, we find in places that they are obliquely laminated in a very marked manner, and if in the neighbourhood of peaty accumulation, they often contain, more or less marked, thin layers of carbonaceous matter. Fine sand, alternating with coarse, is usually supposed to be an aqueous drift, the fine and coarse layers marking the varying strength of the currents. This may be correct in some cases, but in many places the fine layers are due to wind-driftage; as we find in the neighbourhood of the sea, high tides and storm waves will deposit layers of coarse sand, and even shingle, which are subsequently covered up by layers of fine blown sand. This is well exemplified at Lady's Island Lake, Co. Wexford. Even glaciated blocks will sometimes be found in *Æolian drift*, as they may roll into it from higher ground, or drop from cliffs, or be carried into it by high tides.

In some places, on the west coast, as in Ballinskelligs Bay, Co. Kerry, and elsewhere, the *Æolian drift* tends to fill up a portion of the bays, while on the east coast it more usually, in the large inlets, forms banks across a portion of the bay, thus enclosing lagoons.

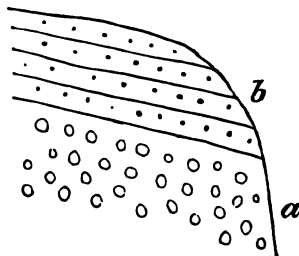


Fig. 4.

* Geol. Mag., April, 1871.

This is evidently due to the different effects which the flow-tide and the wind-waves have on the respective coast lines. On the west coast, in addition to the wind-driftage, there is the flow-tide current and the prevailing wind-waves, all coming from the westward,* which combined forces tend to drive the sand towards the heads of the bays. On the east coast the flow-tide current, in general, acts independently of, or contrary to, both the wind and the wind-wave driftage; for instance, in Wexford Bay the flow-tide is from south to north, up the Irish Sea, while the prevailing winds are from the westward; where their waves met a bar formed across the inner portion of the bay, which has grown into the *Æolian* drift-ridges that separate the Wexford harbour lagoon from the rest of the bay. On the south coast, in places such as Tramore Bay, lagoons have also formed. Here the wind-driftage seems to have had very little to do with the commencement of the formation of the barrier, but since the bank appeared above the water it has added considerably to it.

In some places the movement of the *Æolian* drift is most erratic and difficult to account for. Thus, on Aranmore, Galway Bay, the sands at the S.E. of the island have been for some years regularly going towards the S.W., into the sea, although apparently the most effective and prevalent winds come from the S.W. To the east of Slyne Head, where the winds are similar to those on Aranmore, a vast tract has been stripped of its sand, which seems to have drifted to the S.W.; while on the east coast the sand-hills in the neighbourhood of Arklow are yearly disappearing, and exposing in their place an ancient gravelly beach. Of this sand the fishermen say that it is going to the north-east.

The *Æolian* drift formed, in ages long past, accumulations in the vicinity of the margins of the different seas, and these, if carefully looked for, can be found, although now more or less modified and obscured by vegetation and cultivation. On the slopes of the hills to the north of the plain of Limerick there are vast accumulations of fine sand at about the 350-feet contour line. This would suggest that they are masses of *Æolian* drift that formed near the margin of the Esker sea; more especially as they occur at the same elevation in other places, as among the West Galway hills, and in different places in the counties Wexford and Wicklow. Also in the county Wexford other accumulations of fine sand are found near the raised beaches that margined the seas that stood respectively at about the 100 and the 25-feet contour lines. The "Rabbit Sands" of many other places are probably ancient *Æolian* drifts.

To the wind in the old geological times are probably due some of the

* The result of three years' observation of the direction of the wind on the north, west, and south coasts of Ireland gives as the mean duration for each year:—From the N., 35 days; from the N.E., 24 days; from the E., 27 days; from the S.E., 31 days; from the S., 46 days; from the S.W., 73 days; from the W., 64 days; from the N.W., 58 days; and calm, 7 days (Babington, Meteorological Dept., Board of Trade); or 195 days that the wind and waves act on the west coast.

masses of sandstone found coming suddenly in, like protruded masses, among argillous rocks; as they are in structure exactly similar to *Æolian* sands; while in mass they are like the isolated sand-hills and ridges found in many places in our bays and estuaries, which are being gradually enveloped in mud or such like accumulations. Such masses of sandstone have been recorded in places among the Irish Silurian and Cambrian rocks; also in the Calp or Middle Limestone, and in the Coal Measures; while some of the massive sandstones in the Upper Limestone of Tyrone and Derry were probably wind-formed. Similar sandstones, if looked for, might be found elsewhere.

Summary of conclusions.—That meteoric drift, although too often ignored, is nevertheless not infrequent in Ireland.

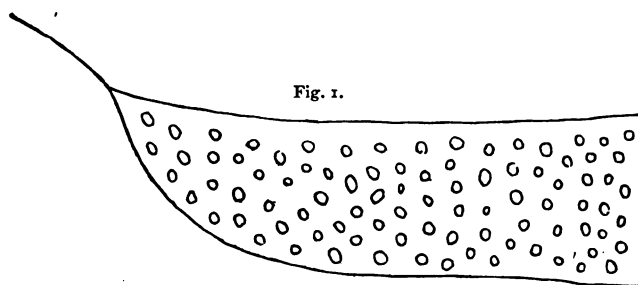
That some accumulations, which have actually been taken for glacial drift, in consequence of their containing ice-dressed fragments, are really, as they now stand, the result of meteoric, or some other non-glacial action; and that caution is necessary in order to avoid similar mistakes in future.

And that many sands and sandstones, now classed as aqueous, may have been accumulated by wind in ages long past.

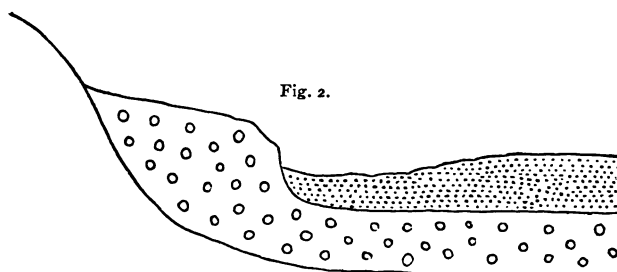
XXII.—AN OUTLIER OF GLACIALOID OR RE-ARRANGED GLACIAL DRIFT ON STRATIFIED GRAVEL (ESKER PERIOD), MOURNE DEMESNE, COUNTY DOWN. By G. H. KINAHAN, M.R.I.A., &c.

[Read December 8, 1875.]

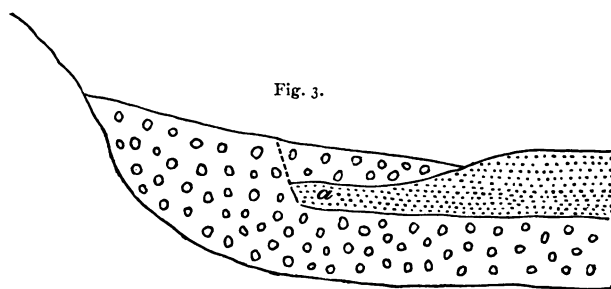
THE outlier of glacialoid drift, the subject of this communication, has been taken for "upper boulder clay," because of its resting on stratified gravels, which themselves repose on boulder clay drift; but a slight examination of the ground in the vicinity shows that this is an error. This glacialoid drift is best seen in the west drift cliff of the small river in the Mourne Demesne, westward of Knockree, one of the minor hills in the Mourne Mountains; and the following will account for the present position of the outlier. During the glacial period, the west shoulder of Knockree formed a groyne against which a mass of glacial drift accumulated, as shown in Figure No. 1. Subsequently, in the "Esker sea period," the glacial drift was in part denuded, a cliff formed, and at its base gravels were deposited (Fig. 2). Still later, as the sea retreated, a bar of sand, which extended for a considerable distance towards the west, was formed from the shoulder of Knockree, making a bar or bank between the open sea and a lagoon or land-locked bay—one of the "Bar-eskers" so common in many places in Ireland. As the sea still retreated, the enclosed space became partly dry land and partly a lake, while the drift cliff at the east end of the enclosing sand ridge, gradually weathered, till eventually it formed a talus of glacialoid drift, that for some distance lay on the Esker gravels (Fig. 3). The sea was now at a comparatively low level, and the water from the lake, behind the sand ridge, percolated through the latter (at *a*, Fig. 3), carrying it away bit by bit, till eventually a passage was opened through the barrier, thereby draining the lake and forming the present river ravine, bounded on one side by glacial drift, and on the other by a cliff having a base of glacial drift, above which are Esker gravels, over which comes a small outlier of glacialoid drift (Fig. 4). That the upper member in the west cliff section cannot be "upper boulder clay" seems evident, as it is only a small local accumulation, not extending for any distance westward along the Esker, which would be the case if a sheet of "upper boulder clay" once covered the gravels—on the contrary, immediately west of the outlier of glacialoid drift, the gravels form much higher ground, and this continues for a considerable distance towards the west. That a lagoon, and subsequently a lake, existed behind the bar at the time specified, seems evident from the sand-banks that are found to the N.E., at the margin of the flat,—the site of the ancient lake; as these seem to have been piled up near the mouth of the principal river that flowed into the lake.



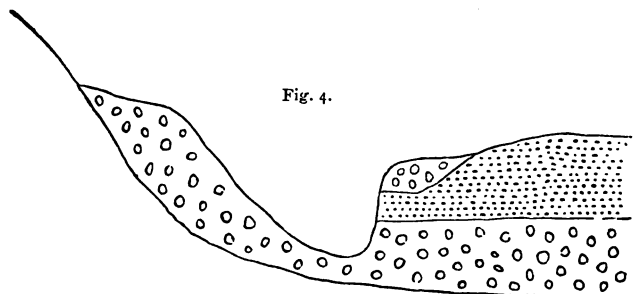
Boulder clay at first.



Boulder clay cliff, with gravel at its base.



Boulder clay cliff weathered into a slope, and the talus covering part of the gravel.



Present river valley cut through the rearranged boulder clay, the gravel, and the underlying boulder clay.

XXIII.—NOTES OF A GEOLOGICAL TOUR THROUGH THE SIEBENGEIRGE AND THE LOWER EIFEL. By JOSEPH NOLAN, M. R. I. A., F. R. G. S. I., of H. M. Geological Survey of Ireland.

[Read April 12, 1876.]

THE paper which I propose to read before the Society this evening, has been drawn up from notes made during an excursion last September, in company with my friend, Mr. Thomas Mayne, F. R. G. S. I.

The districts we visited—the Siebengebirge and the Lower Eifel—certainly the prettiest as well as the most geologically interesting in the Rheinland, are generally well known, and have been frequently described both by foreign geologists and those of our country, notably by Dr. Hibbert and Mr. Scrope; nevertheless, I trust that the short account of our visit which I propose to give may not prove uninteresting, particularly to those who may not have had an opportunity of visiting the district.

THE SIEBENGEIRGE.

The Siebengebirge, or “Seven Mountains,” occupies a tract of limited area at Königswinter on the east of the Rhine, some twenty-four miles south of Cologne. The hills which form this group have for the most part a peaked or conoidal form, resembling, as seen from a distance, a group of volcanic cones, and being, with the intervening valleys, densely covered with foliage, present a most pleasing and picturesque appearance. The higher ground is chiefly formed of trachyte through which basaltic or doleritic masses protrude, and form the tops of many of the hills; while the valleys are mainly occupied by a trachytic conglomerate. Of the hills, the Drachenfels, situated about a mile S.S.E. from Königswinter, is the most important. The rock of which it is composed is so generally known that it is scarcely necessary to enter on any particular description of it here, further than to state that it is a porphyritic trachyte, with large tabular crystals of sanidine imbedded in a base composed partly of that species of felspar, but also largely of oligoclase, with as accessories mica, hornblende, magnetite, and, according to some authorities, augite. It has been observed, too, that the crystals of sanidine are generally disposed in lines having a certain parallelism to each other. This seems to be readily explicable on the hypothesis that the crystals were formed before the emission of the lava, and followed the direction of its motion. Mr. Scrope believes that in the highly crystalline lavas all, or nearly all, the crystals were formed before emission; the fluidity of the mass being due to a more liquid base aided by the interstitial water or steam, which latter, however, he supposes, in other cases, to have been the sole agent of mobility.

This trachyte has long been used as a building stone; and a great part of the magnificent cathedral of Cologne is built of it. Though highly useful for the carved and ornamental portions, it is not very

durable, as it disintegrates easily, and, in the older parts of the building, is full of rectangular cavities from the weathering out of the sanidine crystals.

The hill immediately east of the Drachenfels, called the Wolkenberg, is composed of a felspathic rock, which, though commonly called trachyte, presents some characteristics very different from those of the rock just described. It contains no crystals of sanidine, but abounds with hornblende, and, according to Cotta, the felspar is oligoclase. Mica, of the variety called biotite, also occurs; and in one specimen I found this mineral present in large quantity, apparently to the exclusion of hornblende. The rock has a massive columnar structure, so that the quarries, which are extensively worked in the southeast part of the hill, present a very striking appearance, looking like great amphitheatres flanked with ranges of gigantic columns. In some places, too, an imperfect spheroidal structure, resembling that of basalt, was observed.

Leaving the Wolkenberg, and taking a north-easterly direction for the great Oelberg, the highest hill of the group, we passed over a portion of the district occupied by the trachytic conglomerate before referred to. This rock, locally called *ovenstone*, is well stratified, and contains rounded and evidently water-worn pebbles of pumice and trachyte. It has, thus, all the look of a sedimentary deposit accumulated on the shore of a lake or sea; though some eminent authorities attribute its formation to the bursting of crater lakes.

The great Oelberg is mainly composed of trachyte and trachytic conglomerate. Its peculiar cupola-shaped top is formed of basalt, which seems to occupy a vertical pipe or neck, as if it filled the chimney of the old volcanic vent. This does not seem at all unlikely, as it has been frequently remarked that volcanoes, after having discharged considerable quantities of acidic lavas, very often during their next eruptions emit lavas of a different character.

The summits of the Nonnenstromberg and Petersberg are also composed of basalt, as appears from Dr. H. von Dechen's map, for we had not time to examine them. The Lohrberg is trachytic, while the Löwenburg, the most southerly of the group, is described as a trachydolerite. The following reference to it is found in Cotta's treatise on rocks, p. 192:—"Deiters recognised in the rock of the Löwenburg, in the Siebengebirge, a complete transition grade between trachyte and dolerite. Under the microscope its principal mass appears to consist of crystalline felspar (either oligoclase or labradorite), imbedded in which lie scattered crystals of striated felspar, of hornblende, augite, magnetic, iron ore, and even some olivine. The content of silica here diminishes to 52 per cent.

THE LOWER EIFEL.

The volcanic district of the Lower Eifel lies about twenty miles south of the Siebengebirge, and on the opposite or western side of the Rhine. The most interesting portion is comprised in a strip of country extending in a southerly direction from the Rhine, at Brohl,

to the small town of Mayen, forming the western boundary of the great alluvial plain of Neuwied, north of Coblenz. The chief sedimentary formation here is of the Devonian period, consisting generally of slates and thin-bedded micaceous sandstones, often much indurated and schistose, bearing a great resemblance to the lower Silurian rocks of our own country. Over these beds there occur some occasional patches of the "brown coal formation," a deposit of Miocene age, and the recent loam and sand called *loess*.

There is no evidence as to the period during which the volcanic eruptions commenced, except that they are post-Devonian, having broken through the "grauwacke" and clay-slate; however, from the superposition of most of the lavas to the "brown-coal" formation, it is probable that few, if any, were earlier than the Miocene Period, while they have continued almost, if not actually, to historical times; so that the cones and craters are well preserved, though their lava streams are not always so easily recognised, owing to the thick foliage which, while it heightens the picturesque effect of the landscape, unfortunately conceals much of the geology.*

Commencing our examination of this district on the north, we find at the village of Brohl, and in the wooded valley which extends to the south-west, the peculiar formation called trass or tuffstein. This valley has been cut through Devonian slates and sandstones, and was evidently almost filled with the trass, since which time it has been re-excavated, leaving massive portions of that deposit at the sides abutting against the almost vertical beds of slate and sandstone. It is a very light rock, partly sandy, and partly clay, containing, in a pumiceous base pieces of pumice, slate basalt, &c., with branches and leaves of trees, generally charred, or carbonized. It has little appearance of stratification, and is evidently a *moya* or *debacle* of mud, produced during the prevalence of volcanic activity in the district. It is not necessary to suppose the carbonization of the vegetable remains to be entirely due to the action of heat; yet, when we consider that previous to an eruption the crater and sides of a volcano are often covered with foliage, it is but natural to expect that burned fragments of trees, &c., will occur in *debris* of the renewed explosions.

This remarkable deposit is not only found in the Brohl valley, but also in its branches to the south, through which it extends for a considerable distance. Various conjectures have been made as to the source or sources of it. It has been referred to the Dachsbusch and Hütteberg, or to the Veitskopf volcanoes, situated near the upper part of the Brohl valley, or to the Lummerfeld and Kunksköpfe,

* From a passage in Tacitus it seems probable that an eruption occurred here during the reign of Tiberius. Mr. Scrope fully adopts this opinion, while others dissent from it, believing the so-called volcanic eruption to have been merely an outburst of inflammable gas. See Hibbert's "Extinct Volcanoes of the Basin of Neuwied," p. 254.

situated half-way up the same valley, near the baths of Tönnistein. As, however, from the situations of these volcanoes it would be impossible for the entire deposit to have flowed from any one of them, I think it more reasonable to concur with Mr. Scrope that it proceeded from the crater of Laach—the site of the present Laacher See—occupying as it does a position at the head of all the valleys where the deposit occurs, not only in that of the Brohl and its branches, but also in the district south-east of the Laacher See where trass is found in the valley of the Krufter, a tributary of the Nette, which falls into the Rhine near Andernach.

The manner in which this tuffstein was formed has also been the subject of much conjecture. It may have been produced by the mixing of the fine volcanic dust and ashes with the very heavy rains that accompany or follow eruptions, producing thereby streams of mud such as that which, according to Professor Phillips, filled Fosso Grande after the Vesuvian eruption of 1794. Dr. Hibbert believes it to be due to the bursting of the old crater lake of the Lummerfeld, which he supposes to have been filled with mud from subaqueous eruptions, a second flow being occasioned, as he thinks, by the sudden contraction of the crater basin from the rapid formation of another volcano (the Kunksköpfe) on its margin. Mr. Scrope suggests what seems to me a much more probable theory, viz: that the trass was produced by the bursting of the crater lake of Laach. This basin he conceives to be readily convertible into a lake after an eruption, owing to the fine trachytic ashes or dust that must line its sides and bottom. The water which accumulates either bursts a passage through the light and porous materials which compose the sides, or is discharged through some fissure occasioned by the next eruption, in either case producing a violent debacle converted into a torrent of mud from mixing with the loose fragmentary matters it meets with in its course. Such an occurrence may have frequently taken place from this source, so as to produce in time a considerable thickness of tuffaceous mud.

The trass or tuffstein of the Brohl valley is largely quarried. It has been used in building, but its most valuable property is that when ground into powder and mixed with lime it forms an excellent hydraulic cement. It is chiefly exported to Holland, where it is used in the construction of dykes.

In the vicinity are several mineral springs, the most important being that of Tönnistein. Bubbles of carbonic acid gas ascend in considerable quantity, and lower down on the banks of the stream is a deposit of travertin.

Among the volcanoes of this district the Lummerfeld and Kunksköpfe before referred to are particularly deserving of notice. They are situated south-west of Tönnistein, between the two branches from the Brohl valley that lead respectively to Wassenach and Gleeß. The former is a low, flattish hill, with a large crater breached on the north side, while the latter is a secondary volcano which was formed on the south-western side. It attains, however, a far more considera-

ble height, and its deep crater opens on that of the Lummerfeld, into which it doubtless poured a flood of lava, which flowed from thence northwards into the Brohl valley. The structure of these volcanoes is well exposed in various places. On the south-eastern side of the Kunksköpfe we observed black, or very dark grey sand, with bombs and masses of lava, slag, and scorïæ. The sand abounds with grains of magnetite, generally worn, but often occurring as perfect octohedrons, white and glassy felspar, with much crystalline augite, or possibly hornblende, mica, and olivine, some of the latter being of the clear transparent variety called chrysolite. In it, too, Professor O'Reilly, who kindly examined it for me, found crystalline grains of leucite, and some which appeared to be quartz. In a section near the top of the hill we found coarser sand, with brown slag and intercalated masses of lava that were evidently portions of small flows; also large-sized bombs, some of which had been melted together. The dip in both places was rudely conformable to the slope of the hill, being at a higher angle in the upper than in the lower section. The structure of the Lummerfeld is of a similar character, and was observed at the breach in its crater.

The Laacher See, which has been before mentioned, lies south of the district just described. It is nearly circular in form, with a diameter of about a mile and a-half, occupying a position in an elevated tract composed of volcanic sand with blocks of scorïæ and lavas. These materials, though often irregularly bedded, have in general a double quaquaversal dip, from the lake on the exterior but towards it on the interior of the basin. There can be no doubt that it is an ancient crater, certainly the largest, and probably the oldest in the district, as several parasitic volcanoes of considerable size are situated on its flanks, the most important being the Veitskopf to the north, the Rotheberg to the south-west, and the Krufter Ofen to the south-east.

On the northern side of the lake is a *mofette* or hollow from which carbonic acid gas is continually evolved, which, with the mineral springs of the Brohl valley and some other places, are the only remnants of volcanic energy in the district.

Descending from the Laacher See to the village of Bell we found in its neighbourhood a large deposit of tuffaceous conglomerate, or "ovenstone," so called from the use to which it is largely applied in consequence of its power of resisting heat. This rock is somewhat like that which has been described under the same name when treating of the Siebengebirge. It is of a whitish-grey colour, with fragments, usually rounded, of pumice, trachyte, basalt, and slate rocks. It also contains a considerable quantity of leucite.

South-east from Bell is the interesting district of Neidermendig, noted for its quarries. The lava bed in which they are worked lies deep beneath accumulations of tuffaceous deposits, and shafts are sunk to the subterranean quarries. The rock is extensively used for mill-stones, for which it is said to be well adapted, and it has been quarried for this purpose as far back as the times of the Romans. From its

columnar structure, too, the work is much facilitated, so that little has to be done beyond cutting the blocks into horizontal lengths of suitable size. It is a very tough rock of a dark grey colour, and apparently homogeneous composition. It is vesicular, the vesicles being elongated, probably in the direction of the current, and sometimes partially filled with carbonate of lime, but drusy cavities, lined with olivine, also occur. Crystals of augite are found, though rather rarely, and haidyne, a glassy mineral of a rich Prussian blue colour, is very generally disseminated. In one specimen which I picked up was a very fine crystal which Professor O'Reilly believes to be zircon. Its form was a square prism, terminated with pyramids, and it has a reddish-brown colour, with a slight sub-metallic lustre. I do not know whether this mineral has been before recognised in this lava.

The lava of Neidermendig, though commonly spoken of as a basalt lava, is more properly an intermediate variety between the basalts and trachytes, though more allied to the latter. It might be referred to the class of rocks which Mr. Scrope called *greystone*, "from their prevailing, indeed invariable, tint." In his book on the extinct volcanoes of Central France, that eminent geologist describes a lava at Nugère as bearing "a considerable resemblance to the Neidermendig millstone lava rock." It is vesicular and very felspathic, so as to be scarcely distinguishable from some of the trachytes of the Mont Dore (p. 78). Moreover, at Volvic this lava of Nugère was observed to present a striking contrast to a basaltic lava which crosses it, the latter being "of a black colour and compact, with numerous crystals of augite and bearing the strongest similitude to the basalt of the most ancient plateaux."

The analogue among the older trappean rocks to the greystone of Neidermendig and Nugère is the class intermediate between the felstones and greenstones called basic felstones. They are greenish or purplish in colour, of an apparently homogeneous composition, and fuse readily before the blowpipe. Many of them are vesicular, and have much the look of the volcanic rocks of the present day.

It has been said that at the Neidermendig quarries the lava occupies a deep bed, its outcrop, however, can be seen between the village of that name and Thür, a little north of which it crosses the road as a well-defined ridge, extending to the north-west in the direction of the Forstberg or Hochstein, from which volcano I think it probable it proceeded. On this point I cannot be certain, as I had no opportunity of tracing the lava to its source. Standing, however, on the ridge just mentioned, and looking towards the Hochstein, this seemed a far more probable supposition than that it proceeded from the crater of Laach, an opinion which has been broached by some geologists, notwithstanding that the dip of the lava field is undoubtedly to, and not away from, that crater.

From Thür to Cottenheim the country is uninteresting; but south of that village, on the road to Mayen, is an extensive tract occupied by lava, somewhat similar to that at Neidermendig, and also largely

quarried, though the stone is of inferior quality. This lava flow evidently originated from the vicinity of the neighbouring volcanoes of the Bellerberg and Hochsimmer.

The Bellerberg lies due west of the village of Cottenheim, and about a mile and a-half north of Mayen. On approaching it from that town it presents a broken and irregular outline; but on gaining the summit we perceive it to be the remains of an old volcanic cone, with a large crater, the sides of which in some places form steep crags of brown slag and scorïæ, with a quaquaversal dip. In the scorïæ and slag crystals of triclinic felspar were numerous, and these, as well as the lavas, were often highly micaceous, the mica being biotite. Among the fragments were many of non-volcanic rocks, some which I picked out were quartzites, no doubt altered grits of the pre-existing Devonian strata. The joints in these crags are often covered with an efflorescence of zeolites.

To the south-west of the crater of the Bellerberg, and at some little distance from it, rising through the lava, which surrounds the hill on all sides but the north, are two smaller hills of slag, &c. These are not, as some geologists have asserted, minor volcanoes, the vents of which have been choked up;* for Mr. Mayne, who examined them, found their beds to dip southward, though presenting abrupt escarpments to the Bellerberg. They are evidently the remains of a much larger volcanic cone, within the ruined crater of which the present hill of the Bellerberg was thrown up, as Vesuvius was formed within that of Somma. The main portion of the lava does not seem to have flowed from either of these craters, but rather to have originated from openings on the high ground to the north-west, and sweeping southwards almost obliterated the old cone, which must have been very considerably degraded and shattered by explosions, leaving little but the scarped hills just described. There can be no doubt that some lava flowed from the present crater, as it is breached to the south-east.

The Hochsimmer is situated some distance to the north-east. It is a truncated cone, with a breached crater, the lava from which flowed to the south and south-east towards Mayen, where, with the flows from the Bellerberg, and its vicinity, it forms the extensive tract before referred to.

The deep valley of the River Nette, in which the town of Mayen is situated, lies immediately south of this lava field. From the shape of the ground there can be no doubt that the lavas flowed into the old valley; now they are found at a considerable height above the river, giving us some idea from the very great erosion that has taken place, of the time that must have elapsed since the volcanoes which emitted them were in a state of activity.

Between Mayen and Coblenz the country presents few remarkable features, being mostly covered with alluvial deposits; but in the

* See Hibbert's "Extinct Volcanoes of the Basin of Neuwied."

neighbourhood of Octendunk are slaggy cones, with small lava flows, which time did not permit us to visit. One of these, the Camillenberg, a little south of east from Octendunk, rises to a considerable height, and the lava near the road at Bassenheim is evidently derived from it.

Some miles north of Octendunk, in a branch valley from that of the Nette, between Kruft and Plaidt, is the deposit of trass, which has been before mentioned as being similar to that in the Brohl valley, and also containing charred branches of trees. The volcanic eruptions about here must have been much later than those north of Mayen, as the lava streams descend into the present valleys of the Nette, and its tributaries.

XXIV.—A DETAILED ACCOUNT OF THE EXPLORATION OF KNOCKMORE CAVES IN FERMANAGH. By THOMAS PLUNKETT, Enniskillen.

[Read May 10, 1876.]

KNOCKMORE, as its name indicates, is a large rocky hill. It forms a part of an irregular mountain ridge, which lies along the north-west side of Fermanagh, and stretches from the south-east end of Belmore mountain, and terminates about a mile from the north end of Knockmore, a distance of about thirteen miles. Strictly speaking this line of hills is not a mountain ridge, but only assumes this appearance when viewed from the adjoining valley which bounds it on the north-east side; when examined from a higher stand-point, it is found to be an abrupt elevation forming the margin of an undulating plateau or patch of table-land which extends into the counties of Leitrim and Cavan. This elevated margin runs parallel with lower Lough Erne, and attains an elevation of from ten to fourteen hundred feet above the level of the sea, and from seven to ten hundred feet above the adjoining valley. Its slopes are rather precipitous, and steep limestone cliffs, having an elevation of several hundred feet, form a considerable portion of this lofty margin. Knockmore is nearly circular in form; it has an elevation of nine hundred feet above the sea, and is almost surrounded with very high cliffs: and being partly detached from the main ridge, it presents a bold majestic appearance; hence the name Knockmore is the general term for the surrounding locality. The mountain ridge referred to above assumes a terrace-like form. The outer and lower margin (which includes Knockmore) is entirely composed of carboniferous limestone, and varies from half-a-mile to twenty or thirty perches broad, having a mean elevation of about one thousand feet above sea level. The inner and higher margin is three hundred feet above the limestone terrace, and is entirely composed of gritty sandstone, being the formation composing the whole surface of the plateau referred to above. The rain-water which courses down the sandstone slopes on reaching the limestone surface generally

passes into subterranean channels, and in some instances flows a long distance underground, appearing again at a lower level. In some places these streams penetrate the surface with a swift decline, while at other places they are precipitated down vertical funnel-shaped holes; one of the latter sort I found to measure eighty-four feet deep. These water caves as a rule are found in eroded valleys where the rivulets which flow down the slopes above converge and pass into these hidden ducts, emerging again at the base of the mountain. But there is another class of caverns, numerous in this locality, found on the tops and sides of the limestone summits at elevations varying from one to four hundred feet above the adjoining valleys. These caverns are quite dry, and are generally found almost filled to the roof with rock *debris* and cave earth. When this stuff is cleared out of the cave, a deposit of sand and gravel is nearly always found resting on their rocky floors, clearly indicating the fact that a current of water traversed them at a former period. Of course all caves found in calcareous rocks were not only ducts or channels for, but owe their origin to the agency of, water, a fact that no geologist now-a-days will dispute.

No doubt the positions these latter caves stood in, in relation to the ancient surface (which has disappeared through denudation), as regards level, were similar to those of the water caves of to-day in relation to the present elevated surface, that is to say, the entrances to the caves that are at present traversed by water are from about one to several hundred feet lower than the surrounding elevations in the tops and sides of which the dry caves occur; and arguing by analogy from the known to the unknown, it is but reasonable to assume that an ancient surface having an altitude above these dry caves, similar in extent to the elevated summits which rise above the present water caves, existed at the period when currents flowed through these elevated caverns, but has since been removed by denuding forces.

I have traversed all this mountain ridge from end to end, over and over again, examining its strata, grey, weathered crags, valleys, and ravines; I have also wandered through its dark winding caverns that ramify almost in every direction through its mass, so that I have made myself familiar with nearly all the geological phenomena its surface and caverns present. There is no feature it reveals would strike the eye of the geologist so much as the wasted and furrowed aspect of the limestone surface; it has been sculptured into hillocks and crags, and carved into ravines and valleys of every conceivable shape. These phenomena, together with deep escarpments, bear witness to the extraordinary waste and denudation of the rocky surface during past ages: and whatever may have been the original outlines of this country at the period when man—whose remains, together with Mammalian remains, I found in these ancient caves—roamed over its surface, most assuredly they were not the same as what we see at present. Sir Charles Lyell, in his last edition of the “Antiquity of Man,” propounds a theory respecting the physical geography of

Ireland during the glacial period, and he has arrived at the conclusion that Ireland was in great part submerged during this hypothetical epoch, and that the wide extent of drift spread over large areas in this country "seems to indicate that the land above water formed an archipelago." He further says, "The scarcity of Mammalian remains in the drift favours the theory of its marine origin." Whether this theory, enunciated by such an eminent authority, explains the physical geography of other counties in Ireland during the "glacial epoch," I am not in a position to say, but certainly it does not apply to Fermanagh, either as regards its Mammalian remains or superficial drifts. All the geological features presented by the drift or diluvium clearly show as a rule that it is the *debris* of the underlying rocks, and beyond doubt the result of sub-aerial agencies.

The elevated margin or mountain ridge already referred to runs parallel to lower Lough Erne. The intervening valley is from four to five miles broad, and is thickly studded with dome-shaded diluvial hills. A casual observer would probably infer from their external appearance that they were composed of a mass of drift, but on careful inspection we will find underlying this superficial coating of diluvium the rocky strata which is generally conformable with the contour of the surface of the superficial deposit. I have found beds of gravel and sand on the tops and sides of these hills, and the streams which deposited these beds are at present meandering through the valleys, but at much lower levels and much less in volume than they were originally. There is clear evidence to support the hypothesis that at the time the remains were deposited in the caves at Knockmore, the valley or bed of Lough Erne was much higher than at present. Since that period it must have gradually worn down its bed to a level between two and three hundred feet lower than it formerly was. It is also quite manifest that Lough Erne covered a larger area at a former period. The patches of water called land-lakes, occurring at higher levels, and found at intervals between Lough Erne and the mountain ridge, once formed part of Lough Erne, and remained in depressions as its bed was being slowly worn down, causing its waters to sink or retreat to a lower level and narrower bounds. In these land-lakes, as well as the alluvium adjoining them, the remains of deer, wild boar, and elk have been found frequently. The river gravels—shell, marl, and sand, found under the peat bogs in this country (which were once lakes)—have yielded similar remains, and this year the skull and antlers of a *Megaceros hibernicus* were dug out of a gravel bed in an island in Lough Erne; and several of these noble skeletons were found under similar conditions in Fermanagh. From all these and the following facts I infer that the caves and superficial drifts of Fermanagh are as rich in Mammalian remains as any other place of similar area in Europe.

My explorations last summer were only of a preliminary character. Notwithstanding this, I found between ten and eleven hundred-weight of animal remains, representing a great variety of species and

some hundreds of individuals, as may be seen by the appendix prepared by Prof. Macalister. I also found human remains which—including what I found in Knockninny—would represent nearly thirty individuals.

I thought the foregoing remarks relative to the geological features of this country, especially of the locality in which the bones were found, would not be out of place before giving a detailed account of the exploration of Knockmore caves.

Three years ago I selected several of the loftiest of these caves, and came to the determination that as soon as I conveniently could I would explore them, as I conjectured they would yield interesting remains.

The first I attempted to explore penetrated a high rocky acclivity near the top of Knockmore. The entrance was filled up with rubbish and *debris*, and the opening was so small that it would hardly admit a badger. After clearing away this pile of stuff I found it was a much larger cave than it appeared to be previous to the removal of the *debris*. After excavating a few yards inside the mouth of this cave I found the remains of several animals, and I picked up out of the loam the skull of a pig. I was rather surprised in finding yellow sand and quartz pebbles composing the lower stratum, and still more so by finding imbedded in this layer animal remains which were unquestionably introduced by a current of water: this sand was foreign to the hill or immediate locality. This phenomenon I afterwards found was a common feature in all these ancient caves, although wide and deep valleys now intervene between the sandstone strata, from whence this deposit must have been conveyed by currents of water.

During the progress of my explorations I succeeded in obtaining some very interesting remains, both of human and animal species. Just about this period the Rev. Dr. Haughton paid a visit to this county, and came to my place to examine the remains I had found. He seemed deeply interested with what he saw, and without further delay we drove to Knockmore to examine the caves. In a very short time we procured all the labourers we could find in the neighbourhood, together with all the buckets, crowbars, picks, spades and shovels that were available; and with this little army of sturdy mountaineers we commenced "cave-hunting" in earnest. I rendered him all the assistance I could, but we were not so very successful as I anticipated. Dr. Haughton, having to return to Dublin, proposed paying the labourers if I would superintend the explorations at intervals during the summer, which of course I did with a feeling of interest; and shall now describe the explorations in detail, and in the alphabetical order in which the Rev. Dr. Haughton noted them down. The remains found in each were arranged accordingly.

(A.) The first cave explored occurs about half-a-mile west of Knockmore. The entrance passing into it is on the very crown of a limestone hill, bounded on the north-east side by a valley several hundred feet deeper than the level of the cave, and on the south-west

side the valley is about 150 feet lower than the mouth of the cave. The entrance is vertical, resembling a "pot-hole," but from the inside of the chamber it looks like a large flue passing up through the roof at the south end of the cave. This chamber measures forty-four feet long by twenty-two broad, and the roof is from twelve to fifteen feet high, and is ornamented with stalactites. The walls are also covered with a thick white coating or limey incrustation, which nature has moulded and elaborated into all sorts of fantastic figures; here and there may be found fluted pilasters and beautiful fringed bosses, white as snow, resting on stones which project from the sides of the cavern. Large patches of stalagmite also covered the surface of the floor; in some places it was found twenty inches thick. The walls on all sides are vertical and it presents the appearance, when inside, of a large room. The current of water formerly rushed down the opening through the roof at the southern end, and deposited a large mass of stones and silt which sloped off from the base of the chimney (as I may now call it) nearly to the opposite end of the chamber, resembling in shape talus at the base of a cliff. I commenced to explore by digging a deep trench at the extreme end opposite the entrance, and excavated forward towards this pile which sloped down from the entrance. First we dug through a floor of stalagmite several inches thick, in which we found imbedded animal bones; underneath this coating there was a deep unstratified mass of gravel and silt, together with blocks of limestone, and occasionally a rounded water-worn sandstone would turn up. We found in this bed a large quantity of animal remains. Having now reached the margin of the talus, and as we were excavating on a horizontal line, and had a cutting now four feet deep, fearing the loose blocks of stone resting on the slopes above us would roll down on the men who were digging at its base, before excavating further I had all this stratum of stones removed. They were deposited over the whole surface to a depth of two feet. During their removal I found a considerable quantity of animal bones, especially those of the horse and deer. Underneath these stones there was a compact bed composed of silt and gravel, and occasionally very large blocks of limestone would be met with. As we advanced with the digging the depth of the cutting increased from four till it ultimately reached a depth of twelve feet. Animal remains were found interspersed all through it, down to the lowest bed we excavated. I found human bones in two places in this bed: the first were found fourteen inches from the surface, that is, fourteen inches from the surface of the bed of silt; portions of skulls and teeth together with other human bones were found two feet below the surface. Nearly all the animal remains were partly covered with an incrustation of carbonate of lime, and several of them were bound up in a matrix of stalagmite dug from the sides of the floor of the cave. A very handsome lump of this material was carefully cut from the surrounding mass, and out of the side of it the leg-bone of a deer protruded. This may now be seen in the Museum of Trinity College, Dublin.

Having no way of removing the stuff out of the cave, there was no room to explore it deeper. Had I been able to have done so, probably I would have found a greater variety. The quantity we did find would weigh about four hundred-weight. I might here observe that in my opinion the greater part of the animal remains were introduced by the agency of water, and this observation would apply to nearly all the caves I explored. Owing to the high elevation of some of these caves above the surrounding valleys, one feels it very difficult at first glance to believe that such extraordinary changes of surface have taken place since the remains were deposited in the caves, but the *detritus* found in all these caves bear overwhelming evidence of this great truth. For instance, fifty per cent. of all the *detritus* turned over in the cave under consideration was composed of chert, which is nowhere found in the hill, but a vein of this mineral runs along the valley adjoining it. Some water-worn sandstones were also found in it, which must have been carried from the elevated sandstone margin about a quarter of a mile distant in the opposite side of the valley.

(B.) The next cave in the order lies about half-a-mile south of A, and opens out on a grassy ledge of rock in the face of an escarpment on the south side of Knockbeg. I ordered the men to commence digging on the margin of the ledge, knowing from experience that all these caves in calcareous rocks have crumbled down by the action of frost, rain, &c., sometimes for a distance of several yards. Digging this space forward to the entrance, very large blocks of limestone were turned over, underneath which I found charcoal and some animal remains. When we had excavated up to the entrance and proceeded a few feet within, I found the deposit in the bottom of the cave so shallow, and as the cave appeared to grow narrower as it extended inwards, I came to the conclusion that it would not likely yield any objects of interest. I therefore gave it up and repaired to

(C), which is very curiously formed, and occurs in the centre of a slightly elevated and rugged patch of limestone; the entrance is partly surrounded by brushwood, and partly veils from view the three perpendicular funnel-shaped holes which blend into one at the bottom, and are perfectly cylindrical in form, as much so as the cylinder of a gun. They pass down to a depth of twenty-two feet from the surface, and are filled with *debris* to this point from an unknown depth. There was an opening at the side of this cave, just on a level with the floor, which passed into a deep fissure. Were it not for this opening we could not have explored this peculiarly-formed cave. When the stones and *debris* were thrown into this fissure they fell to an enormous depth, as we could hear the rumbling noise caused by throwing in the stones die away in the bowels of the mountain. After clearing away eight or nine vertical feet in this way we ceased working, as we met with a very large stone that was tightly bound against the sides of the funnel, and seemed to have formerly fallen from above and stuck in the throat of this vertical shaft. Thinking it might be a risk

to break it with the sledge, lest we might cut the branch on which we were perched, and be precipitated into the dark chasm beneath, and our bones become interesting "finds" for future adventurous explorers, we ascended the ladder and bid it a final farewell. In every layer of *debris* we turned over in this cave we found copious remains of animals. The remains of the dog were very common. I picked up at different levels nine skulls belonging to this species.

(D.) The fourth cave in the order lies a short distance in an easterly direction from C. It pierces a slightly elevated escarpment, and has its entrance near the base, or nearly on a level with the adjoining till or drift. This cave yielded most interesting relics which I shall presently describe. The entrance to it before being explored was very narrow, so much so that I had to crawl in on "all-fours." Passing a few feet inside, it enlarged to a height of four feet, and a length of nine feet. The surface was entirely covered with dry angular limestones of various sizes. From the contour of the walls, and general appearance of the interior, it was quite evident that this was a very large chamber, almost filled to the roof with rubbish and all sorts of *debris*. On examining round about the entrance, which opened into an indentation in the side of the rock, it appeared quite manifest that the cave at one period extended about ten feet further out, and that this much at least had been "weathered" off. This is a common feature in all caves opening out in limestone escarpments or slopes. By my directions the men commenced to dig ten feet from the entrance; after digging several feet down they struck the rocks *in situ*. In clearing away this pile up to the door of the cave, large square blocks and flags of limestone were removed from what was the original floor of the cave, and underneath which we found a quantity of charcoal; out of the same bed I picked up a quantity of broken bones. A great many of these bones were subjected to the action of fire; afterwards when Rev. Dr. Haughton and Professor Macalister examined these burnt bones, I was surprised to find that some of them were human remains. Does this phenomenon favour the hypothesis that cannibals occupied the cave at one period of its history?

I also found on the same floor, associated with the bones, the iron blade of a knife about four inches long; also an iron dagger about twelve inches long. Both of these weapons are covered with a very thick incrustation of an oxide of iron, and were of a very ancient type. I also picked up out of the same spot broad sea shells, and a whet-stone, together with the skull and antlers of a large deer. One of the antlers was cut, apparently with a knife, probably such as I found associated with it. Another piece, about the length of the handle of a dagger, was cut half through, and bore the appearance of a round stick, cut half through all round with a pocket-knife. I infer from the way in which these things were found, and the antlers of the deer being cut so, and its being found in the "kitchen midden," that the ancient cave-dwellers lived by the chase. Having removed all the stuff

covering the space before the entrance to the cave (which formed a deposit from three to four feet deep, and under which I found the interesting objects just described), I proceeded to explore the interior. Owing to the excavations outside, the entrance to the cave assumed much larger proportions than it had when I first saw it. Instead of only two feet, its former height, it was now over six feet, which facilitated very much the removal of the deposits within. The surface, as I have already said, was covered to a depth of from two to three feet with dry blocks of stone of various sizes. Bones of deer and various other animals were found in the interstices between, as well as underneath, these stones. The removal of this stratum of stones opened up the entrance to another portion of this chamber, and after clearing away the angular stones which also covered its surface, we could walk from the entrance to the extreme end of the cave, which was now a distance of forty feet, without any difficulty. As there was a considerable incline from the entrance to the end of the cave, we could not so conveniently excavate forward from the entrance. Finding that it would be much more convenient, I directed the men to commence at the extreme end, and as the deposit in the cave consisted almost entirely of silt and small angular stones, it was much easier excavated from this end. Moreover, as we removed it by turning over layers two feet deep, and the material being loose and porous, the bones could be seen protruding out of the face of the cross section or cutting, and could be easily pulled out with the fingers. In this way I removed a human skull which I saw through a little chink in the face of this scarped cutting, and had we been using the pick or spade which would have been absolutely necessary, had we commenced at the other end, this skull, as well as a great many of the bones, would have been broken into fragments. As the small stones and bones were picked out in the face of the cutting, the clay in which they were imbedded fell forward. This clay was then carried outside, and re-examined in the light. There were no finite layers found in this deposit. The material was the same as I have described above, from the surface under the stones to the bottom of the cave; and I found both the human and animal remains all through its mass from the top to the bottom. In order to give an idea of the places in the cave-earth or *debris* where I found human remains, I divided it into upper, middle, and lower, and marked the bones as I found them accordingly: in other words, I found human remains about three feet below the surface, also pieces of skulls, jaw-bones, &c., eleven feet from the surface, and the deepest I found were buried sixteen vertical feet from the surface. There was no weapon or work of art associated with those remains, nor any traces of charcoal. Of course I do not include the remains I found in connection with the dagger, &c., outside the cave in the above summary.

That this mass of silt, sand, and stones was carried into the cave by the agency of water I do not entertain the slightest doubt. A

great many of the animal remains were probably introduced the same way, and if the currents at that remote period have been intermittent, animals or man may have sought it as a shelter and died there. Whether these remains were introduced by water or otherwise, one fact I am certain of, viz., that the rock *debris* under which they were found was carried into the cave by a current of water. Since that period it has never been disturbed, and after carefully examining this overlying material, I find the greater part of it has been transported from a distance. There is strong evidence pointing to the presence or operations of ice in this region since these remains were deposited. Opposite the door of the cave there is a small "drift" hill, and large sandstone boulders are found on its sides. Its skirts rest a few feet below the entrance to the cave.

(E) is a small cave opening out in the side of a wide ravine, and was explored in the presence of the Rev. Dr. Haughton. It yielded but few remains. Several feet underneath a deposit of grey cave-earth some animal remains were found, including bones of a large deer. Also about three feet from the surface charcoal and some human remains were found. Amongst the human remains there were a few fragments of a very thick skull. No works of art were found in this cavern.

(F), which is the last of the series of caves under consideration, is but a very small one, and penetrates a rocky declivity very near the top of Knockmore. When I commenced to explore it the entrance was very small, so much so that an ordinary sized dog could hardly crawl into it; but when the rubbish which closed up the door was removed, the entrance measured four feet high. The deposit inside consisted of dark, loam yellow sand mixed with quartz, pebbles, and gravel. In the loam I found the skull of a pig, which when living must have worn a very long snout; also a variety of remains representing other animals. Imbedded in the yellow sand I found the leg-bone of some animal such as the pig or deer, and certainly it must be of an extraordinary antiquity, as the sand was undisturbed since it was deposited by water. This sand and gravel is the waste of sandstone grit which forms the higher margin of the elevated plateau referred to at the beginning of this paper, and is entirely foreign to the hill in which the cave is; and two deep valleys (fully two hundred and fifty feet lower than the cave) intervene between the sandstone grit and the entrance to the cave. All these extraordinary changes, which have occurred since pre-historic man and these wild animals inhabited this country, have been brought about by the slow operations of sub-aerial agents, such as ice, snow, and running water, in which carbonic acid is present.

I have given a simple detailed account of the exploration, or rather partial exploration, of the Knockmore caves, which has been only of a preliminary character. Having gained some knowledge of cave digging last summer, I hope to make greater progress during the ensuing season. Were it not for the stimulating visits of the Rev.

Dr. Haughton, and the facilities afforded by him, I would have made but little progress. Having made such a fair beginning, I hope that in a few years we will get abreast of England, France, Switzerland, or Belgium, in "cave-hunting," and disprove the theories of English geologists regarding the absence of Mammalian remains in this country.

XXV.—ON A PROBABLE ORIGIN FOR MANY MAGNESIAN LIMESTONES AND DOLOMITES, FOR THE SERPENTINE STREAKS IN VERDE ANTIQUE MARBLE, AND FOR THE SERPENTINE FOUND IN EOOZON CANADENSE AND OTHER LIMESTONE FOSSILS. By WILLIAM LOWTHIAN GREEN, Minister of Foreign Affairs to the King of the Sandwich Islands.

[Read June 14th, 1876.]

THE origin of most of the old limestone deposits seems now to be admitted to have been either ancient coral reefs or islands, or else a globigerina mud, such as the "Challenger" Expedition has shown to prevail at present at the bottom of the ocean, in depths of not more than about 2250 fathoms. In the central portions of the Pacific Ocean, as is well known, there exist two classes of rocks only, coral rocks and volcanic rocks; and this not only applies to what rocks may appear above water, but the soundings of the "Tuscarora" and "Challenger" seem to indicate that this is the case also over all the bed of the Central Pacific. The area of this region, it should be observed, over which these two kinds of rocks are found, to the exclusion of all others, is not very far from being as great as that of all the continents of the earth put together—that is to say, we have here visible an area of rock masses, now in process of formation, comparable in extent with all the known geological formations on the face of the earth. I say now in process of formation, for the ooze and the red clay and the coral is being deposited, or is growing and increasing daily, whilst the lava is either now pouring out white hot before our eyes, or it exhibits evidences of having been so poured out in times not, geologically speaking, remote.

This lava is almost identical in composition over this great region: that is, it is usually a dark-coloured basic lava, almost invariably containing a large proportion of the mineral olivine. The Hawaiian group of islands consists of an immense mass of this description of lava—I say an immense mass, for the fact of the enormous quantities of lava poured out by Pacific Ocean volcanoes seems not to be properly appreciated by European geologists. It is a fact worthy of their attention that the single island of Hawaii alone contains about as much volcanic matter (mostly solid lava) as Mr. Mallet estimates as representing (unchallenged, as far as I am aware), "not very inadequately, the totality of volcanic action [over the whole earth] since the Tertiary or even a more remote epoch," and which he esti-

mates at 2616 cubic miles, or 400 volcanic cones of 6.54 cubic miles each.* The Hawaiian Surveyor-general, Professor Alexander, estimated, at my request, roughly the cubic contents of the purely volcanic island of Hawaii as containing not less than 2600 cubic miles of lava above the sea level only. The two acting volcanoes of Mauna loa have poured out about one cubic mile of lava (not tufa) during the last forty years;† at which rate the whole island might have been produced in 104,000 years, which would certainly not take us very far back into the Tertiary Period, according to any estimate whatever.

The Hawaiian Islands are more or less surrounded by coral reefs, the island of Hawaii less so than the others, for one reason, because the lava has kept pouring into the sea along most parts of the coast during the past centuries, and has not given the coral an opportunity to form to so large an extent as on the other islands. Now it is a fact that wherever the lava runs into the sea, or wherever the waves have an opportunity of breaking against the lava, or against the tufa, over the group, a large quantity of olivine sand is formed. The felspar, the other mineral of which this lava is mainly composed, gets ground up to powder, and disappears—indeed, it is almost always in the minutest grains to begin with—whilst the olivine, a much harder mineral, and in grains from the size of a bean or a pea downwards, forms the main component of the sand of the seashore wherever the sea meets the lava; or else the olivine sand gets more or less mixed up with the coral sand, where the two classes of rock are in close proximity. A great deal of this olivine sand is of the finest possible quality; indeed it is often so fine that, although a much heavier mineral than carbonate of lime, it will often, where both are washed by the waves, settle on the top of the coral sand, and I have often scraped the almost pure, fine olivine sand from the top of a coral-sand beach. This mixture of the two sands is common over the group, extending 400 miles, from Hawaii to Bird Island.

I find this olivine sand also insinuates itself into the pores and openings of the coral reef-rock; and I have sent some specimens of this olivine-impregnated coral rock to the Hawaiian Department of the Philadelphia Centennial Exhibition, along with specimens of Hawaiian lavas and rocks generally.

As Mr. Dana has observed, these coral sand-rocks consist of different classes, and are probably being formed continually by the cement produced by the solution of carbonate of lime. There is the coarse coral reef-rock, the beach coral sand-rock, and the fine-blown coral sand-rock. A close examination of many of these rocks will constantly show grains of olivine more or less mingled with coral. Indeed there is every grade of mixture, from all coral to all olivine. Very often the olivine sand-rock will be found to run in streaks

* See Mr. Mallet's Paper on Volcanic Energy, in the Transactions of the Royal Society, Vol. 163.

† See Brigham's "Hawaiian Volcanoes."

amongst the coral sand-rock, so that in the course of time, when the coral sand-rock comes to be metamorphosed into a limestone or a marble, the olivine sand-rock would probably suffer the change which that mineral is well known to experience, namely, into serpentine. The rock would then be what is called *verde antique*.

Precisely in the same way, the fine olivine sand penetrating and filling up openings in corals or in foraminifera, might become, in the course of time, converted into serpentine; and the fact of our now finding corals and coral rocks in the Pacific with their pores filled with olivine sand seems to suggest the mode in which the *Eozoon Canadense* may have had its porous skeleton of carbonate of lime filled up with what is now serpentine, and which is found to be the usual filling.

Whether a mixture of coral sand-rock and olivine sand-rock may become a magnesian limestone by solution and recombination is a question for chemists. It is well known that olivine, or silicate of magnesia, is readily dissolved and decomposed, and that carbonate of lime is also easily dissolved in water containing a small portion of carbonic acid. Under certain circumstances, then, we have to suppose that the silica of the olivine may be carried away in solution, whilst the magnesia may unite with the carbon to form carbonate of magnesia, this effect taking place either wholly or in part, as far as the solution of the carbonate of lime is concerned. Thus it is found that the two classes of rocks or minerals, carbonate of lime and carbonate of magnesia, are often found mixed in all proportions. The olivine tending to form in streaks or layers also would help to explain, if this metamorphosis be possible, what Bischoff and others have always considered a difficulty in the conversion of limestone rock into dolomite, that is, the irregular and arbitrary way in which it often appears to have been effected, and which seems at first sight so inconsistent with the idea of a metamorphosis of the carbonate of lime in a solution containing magnesia. The irregular and arbitrary mechanical distribution of the olivine sand amongst the Hawaiian coral sands and coral rocks and coral sand-rocks seems to clear up this difficulty, if we may admit the probability of the metamorphosis.

Mr. Murray, of the "Challenger" party, when here, suggested to me that the yellowish looking grains of coral (?) in many of our oolitic looking coral, sand, and beach rocks, and which are now in process of forming, looked as if they had been, or were being, metamorphosed. It has occurred to me that possibly the olivine grains amongst our coral sands may become coated thickly with successive layers of carbonate of lime, and then the whole be converted together into a carbonate of magnesia. But I merely throw out these ideas by way of a suggestion to those chemical mineralogists who may have an opportunity of analyzing such recent coral rocks, where a mixture of olivine sand either is found to occur, or may be suspected to have occurred at an earlier stage of their formation.

Whilst upon this subject, I would venture to suggest, for the con-

sideration of Professor Wyville Thompson, and the gentlemen of the "Challenger" Expedition, whether the red clay (alumina and oxides of iron) which they consider to be the "ash" of the organically formed bodies, after the carbonate of lime has been dissolved, may not be a volcanic residue, distributed mainly, perhaps, in the first place in the shape of volcanic ashes. In melting the snows of Arctic and Northern regions a residue of volcanic dust is usually found, the distinction being, in the cases of the red clay, or residue from the globigerina ooze, that the more soluble volcanic components may have been dissolved under the influence of the high pressure at great depths, as well as the carbonate of lime. The immense proportion of oxide of manganese nodules, which the "Challenger" dredging brings up from the bottom of the ocean, has most probably a volcanic origin also, as it is a common constituent of Pacific ocean lavas; and it appears to exist at the bottom of the sea in quantities too great to be ascribed simply to the manganese, which may have existed in the organic bodies themselves. Its being often found also surrounding true volcanic pumice is a strong indication of its volcanic origin.

The difficulties which have presented themselves to Messrs. Rowney and King, and others, on finding "mineral" matter, instead of organic substances, in what are claimed to be limestone fossils seem to disappear when we remember the close connection which now exists, and has existed in ancient periods, between coral reefs and basaltic islands, as well as between old limestone and old volcanic rocks. It may be that extensive coral reefs, or great organic deposits of carbonate of lime, could not form in an ocean, of which the shores and islands were composed of purely granitic or quartziferous rocks. The lime of the basic lavas may be necessary, when dissolved and washed into the ocean, to the formation of extensive coral reefs, whilst the olivine sand which remains, and which seems to take the place, in the Central Pacific, of the quartz sand of continental shores, is always ready to fill up the crevices in the coral rocks, and the pores of the coral animals, or to replace their sarcodic bodies with a mineral which we know will change to serpentine. This may have been the case in the Palæozoic seas; and, although we may be ready to admit to how great an extent "the dust we tread on was once alive," we are reminded by what is going on to-day over the central Pacific area, that in the ancient oceans volcanic action was probably at least as great as it is at present, or as it has been in recent geological periods in the Pacific; and that this volcanic action may have distributed amongst the organic deposits of the Palæozoic seas all the exclusively "mineral" substances, now mostly in a metamorphosed state, which we find in the old limestones and dolomites, and of which it might otherwise be difficult to conceive the origin, the whole being in point of fact the volcanic basic elements in a new form, of which the old granites and highly siliceous rocks, their contemporaries, are found more or less deprived.

XXVI.—ON SOME OF THE CONDITIONS INFLUENCING THE PROJECTION OF DISCRETE SOLID MATERIALS FROM VOLCANOES, AND ON THE MODE IN WHICH POMPEI WAS OVERWHELMED. By ROBERT MALLET, F. R. S., M. R. I. A.

[Read June 14th, 1876.]

DIFFERENT volcanoes, or the same volcano at different times, present mainly two distinct eruptive features, viz., the erupted matter is mainly or entirely mineral matter in fusion (lava), or it is solid material separated into fragments more or less comminuted, which are ejected at various temperatures below that of bright incandescence, but short of that necessary for the fusion, or soldering together, of the discrete material. With the eruptive matter of this latter sort there are also frequently thrown out masses or flakes of more or less plastic or viscous lava, which has either not been brought into perfect fusion, or has been cooled below that point by the contact of discrete matter at a lower temperature. These eruptive characteristics are often alternately displayed in more or less rapid succession by the same vent, while in a state of sufficient activity. And such has been for about three centuries a salient feature in the eruptions of Vesuvius, and also, though less markedly, of the present crater of Etna or Mongibello. A general prevalence of discrete incandescent ejecta, rather than of liquid lava, seems to be chiefly attributable either to a want of a sufficiently high temperature, at the deeper volcanic foci, due to circumstances which I have elsewhere endeavoured to trace in outline to their physical cause (Phil. Trans., 1873), or to a more infusible and otherwise intractable character of the rocky materials constituting the beds from and through which the volcanic ducts, or throat, for the moment, ascend. Towards the close of eruptive paroxysms the same volcano, Vesuvius for example, which has at an earlier and more energetic stage poured forth floods of lava, may give forth less and less of that, and more of heated discrete material, such as dust—commonly, but most unfortunately, called ashes—lapilli, pebbles, and stones of various magnitudes. And probably reduction of subterranean local temperature, chiefly due to the vast amount of heat carried off by the volumes of ejected steam, may be connected with the alternate change from showers of discrete matter, which often present themselves at the early stage of eruption, before the volcano has gathered full force, and again at the end precede the final cessation of eruption for the time. Still some much wider cause must exist, which limits the temperature of eruption of the same volcano, either permanently or for lengthened periods, to one of incandescence, or far below that of liquid lava. Thus the first recorded eruption of Vesuvius, after its long repose, in A. D. 79, in which the ancient cone of Somma partly collapsed, and fell in, and partly was scattered in dust and fragments, was not attended by any flow of lava; and, although many eruptions are recorded during the next 900 years, or thereabouts, no mention

is found of an outflow of liquid lava in any one before that of A. D. 1030. It must be admitted that this negative evidence, from observations made in times so ignorant and barbarous as those of the first 1000 years of our era, cannot be accepted as conclusive. The general fact, however, seems to be sustained by many other examples in different parts of the world, which tend to show that some cosmical cause, and not the mere gradual gathering and decay of eruptive effort, limits the temperature of many vents to that of incandescence. Such differences, whether permanent, or having long cyclical changes in exaltation or depression of temperature, as indicated by the ejecta, admit of complete explanation upon that mechanism to which I have assigned the nature and origin of volcanic heat and energy (Phil. Trans., 1873), but seem to me extremely difficult, if not impossible, to be explained upon the long-accepted notion that the heat is derived only and always from a direct connection with a liquid nucleus, or with seas of molten matter beneath our earth's surface.

I propose here to consider merely some of the circumstances attending the ejection of discrete or fragmentary material from volcanic vents, and more especially from that of Vesuvius; and to try whether those conditions may not throw some new light upon those under which the ancient city of Pompei was overwhelmed, and which, though referred to by many authors, and at various periods, appears to me still much in need of elucidation.

A volcanic vent, while in the phase of blowing out, with steam and certain gases, discrete or comminuted material, may be roughly presented to the imagination as a more or less goblet-shaped cavity, the bottom of which is in connection in one, or in several places, with a tube or duct rising from the deeper foci of volcanic activity, the goblet and subjacent tube thus resembling in some degree a funnel or tundish, through which liquids are commonly poured.

Were we to provide such a funnel with a stream of air or steam, rushing upwards through the tube in irregular gushes, and carrying upwards solid material such as sand along with it, much of which lodged in the goblet, and, shedding down towards the centre, more or less obstructed the tube, we should have a tolerable model both of the form and mode of action of a volcano expelling dust and stones, &c., without lava. This, though the most general, is not invariably the form of volcanic mouths ejecting discrete material, as will be presently again alluded to. Within the cavity of the bowl-shaped funnel, always filled to a considerable extent at its lower parts with incoherent material, an almost continuous mechanical agitation is maintained amongst the discontinuous matter by the gushes of steam and gases issuing from the ajutage or tube at the bottom, which blow their way through the material already contained in the funnel, and occasionally bring up fresh supplies of like material to it, while the steam gushes often blow out more or less of like material above and over the lips of the funnel; but it does not appear to me that this "trituration," long continued and considerable though it must be, can

be admitted as the principal cause of the general rounding ascribed to attrition, which is so characteristic of most of the fragmentary matter ejected from volcanoes, for almost all the matter which is blown up into the goblet or crater appears to be already more or less rounded, whether by partial fusion, or by attrition, or by both. Were it not so, sharply angular fragments, almost free from rounding, could scarcely fail frequently to present themselves, having got enveloped in other material, and lain *perdu* in corners where the material within the crater chances to be but little agitated. Still the rounding, which goes on within the crater itself must be considerable, for of the discrete material blown by the gushes of steam into the air, a large portion falls back into the goblet or crater again, to be again blown out, and fall back. A certain amount of sorting as to the sizes of the rounded fragments goes on by this process. Whatever is ejected, whether large or small, above the lip of the crater, starts with about the same velocity, depending mainly upon the velocity of the steam gush, and the more or less directness with which it is enabled to act upon the matter it blows out; the larger stones, however, go much higher than the finer material reaches, because the work stored up in the larger mass bears a greater proportion than in any smaller one to the resistance which it experiences. The trajectory of the larger stones, though in the same direction, perhaps, initially with the finer fragments, becomes more or less disturbed by contact with the smaller particles, along with which they are projected, and through which they pass with a relatively higher velocity as the whole mass rises through the resisting air. These larger fragments are thus, both by rising higher and by lateral deflections of trajectory, more readily thrown out over the lip of the crater than are the smaller fragments, which, if not small enough to float for a time in the air, and be carried off laterally by the wind, drop back into the crater whence they came. In the greater steam gushes, however, the whole mass of fragmentary matter ejected rises often to a great height, pushed on and floated, as it were, upon the spreading summit of the issuing steam jet, which, partly by condensation, partly by loss of tension, as its volume is free to increase, leaves the irregular and by no means very dense mass in the air as a black and opaque cloud; above this the larger stones are seen to rise still higher, and then to begin to fall either through it, or beside it, dependent upon the force and direction of the wind at the moment. The heavier pebbles and lapilli are almost immediately seen to rain out, as it were, from the lower part of the great dust-cloud; and where the height of projection has been considerable, and there is any sensible wind, to fall more or less outside the crater. The finer ejected fragments of volcanic dust, &c., float in the air, and are carried on by the wind to a distance dependent upon their own magnitudes and densities, upon the velocity of the wind, and upon the height at which they commenced to fall, the cloud spreading out more or less laterally as it travels.

The sorting, however, of the fine particles in the air still con-

tinues. Every one of these fine particles (as may be inferred from the principles established by Professor G. G. Stokes, in his admirable paper on the "Effect of the internal Friction of Fluids on the Motion of Pendulums," in which he treats of the suspension of rain cloud, and slow descent of rain drops through the air (Camb. Phil. Trans. Vol. ix., part ii., p. 8, 1850) speedily acquires a terminal velocity, after which its motion of descent is no longer an accelerated one—as in the case of large masses, to the descent of which our atmosphere offers comparatively scarcely any resistance where the acquired velocity is less than that with which air rushes into a vacuum—but the movement of descent becomes uniform, so that the path in space of any one particle in air, moving horizontally with a given velocity, is simply a right line (assuming the density of the atmosphere the same at all such heights as are here in question) dipping downwards, the slope being more and more gradual as the particle is smaller. The distance, therefore, to which any particle will be carried by a given velocity of wind, assuming its form spherical, may be calculated upon the principles enunciated by Stokes, the chief elements being the diameter or magnitude of the particle, the density of its material, and that of the air which carries it, and the horizontal velocity of the wind.

The velocity of descent of the very finest particles, or absolute microscopic dust ejected by volcanoes, may thus be so small that they remain suspended in the air for days or even for months, and during this time may be carried by the wind to enormous distances, and spread out laterally over immense areas. These conditions of the transport of volcanic dust appear to have been hitherto most imperfectly understood by volcanic authors, many of whom appear to suppose that the distance to which such dust is occasionally carried is somehow directly connected with the ejective power of the volcano.

The distance to which the dust travels has indeed this one point of connexion with the eruptive violence, that the higher the cloud of mixed volcanic dust is sent into the air, the longer will be the path of every particle in it before it can return to the ground; but there is no other point of connexion, the distance to which the pulverulent material travels, after its ejection to a given height, depending simply on the size of the particles, their form and density, and the velocity of the wind that transports them, for we need not here enter upon some subordinate, though by no means insignificant conditions, that affect the distance of transport, such as electrical excitement in the particles or in the air, ascending or descending air currents produced by sun heat or by nocturnal radiation, or the effects of the particles encountering rain, which, by wetting them, alters both their density and their effective magnitude, or causes many dust particles to aggregate and cohere.

Few descriptive accounts of volcanoes are to be found which do not refer to the enormous distances that dust projected from the volcano of Tomboro, in the Eastern Archipelago, has been known to travel before reaching the surface of the ocean or earth, as though it

be admitted as the principal cause of the general rounding ascribed to attrition, which is so characteristic of most of the fragmentary matter ejected from volcanoes, for almost all the matter which is blown up into the goblet or crater appears to be already more or less rounded, whether by partial fusion, or by attrition, or by both. Were it not so, sharply angular fragments, almost free from rounding, could scarcely fail frequently to present themselves, having got enveloped in other material, and lain *perdu* in corners where the material within the crater chances to be but little agitated. Still the rounding, which goes on within the crater itself must be considerable, for of the discrete material blown by the gushes of steam into the air, a large portion falls back into the goblet or crater again, to be again blown out, and fall back. A certain amount of sorting as to the sizes of the rounded fragments goes on by this process. Whatever is ejected, whether large or small, above the lip of the crater, starts with about the same velocity, depending mainly upon the velocity of the steam gush, and the more or less directness with which it is enabled to act upon the matter it blows out; the larger stones, however, go much higher than the finer material reaches, because the work stored up in the larger mass bears a greater proportion than in any smaller one to the resistance which it experiences. The trajectory of the larger stones, though in the same direction, perhaps, initially with the finer fragments, becomes more or less disturbed by contact with the smaller particles, along with which they are projected, and through which they pass with a relatively higher velocity as the whole mass rises through the resisting air. These larger fragments are thus, both by rising higher and by lateral deflections of trajectory, more readily thrown out over the lip of the crater than are the smaller fragments, which, if not small enough to float for a time in the air, and be carried off laterally by the wind, drop back into the crater whence they came. In the greater steam gushes, however, the whole mass of fragmentary matter ejected rises often to a great height, pushed on and floated, as it were, upon the spreading summit of the issuing steam jet, which, partly by condensation, partly by loss of tension, as its volume is free to increase, leaves the irregular and by no means very dense mass in the air as a black and opaque cloud; above this the larger stones are seen to rise still higher, and then to begin to fall either through it, or beside it, dependent upon the force and direction of the wind at the moment. The heavier pebbles and lapilli are almost immediately seen to rain out, as it were, from the lower part of the great dust-cloud; and where the height of projection has been considerable, and there is any sensible wind, to fall more or less outside the crater. The finer ejected fragments of volcanic dust, &c., float in the air, and are carried on by the wind to a distance dependent upon their own magnitudes and densities, upon the velocity of the wind, and upon the height at which they commenced to fall, the cloud spreading out more or less laterally as it travels.

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were a proof of the violence and power of that volcano. Dust, in reality, may travel much farther after projection with very little violence, but from a very lofty cone, than from a low cone like that of Monte Nuovo, had its activity continued, or some of the Puys of Auvergne, though these were violently and explosively active. Where the mass of discrete matter projected at one gush is large, and where, as is most commonly the case, the volume of lapilli, pebbles, and large stones bears a considerable proportion to that of the finer dust, then the whole mass is projected to a considerably greater mean height than would be possible as respects all the finer particles, if none larger were present; for, as the mixed mass ascends, and the finer particles, exposed to a relatively greater aerial resistance, tend earliest to lose velocity, while the larger particles, lapilli, &c., having a greater stored up energy and relatively less resistance, increase in their velocity relatively to that of the finer particles, so are the latter forced onwards by the larger fragments towards the upper part of their ascent, and are thus carried to a greater height than they could have ascended to if alone. There seems, therefore, no reason to doubt that where a mass of volcanic fragments of mixed magnitudes is projected, the height of ascent of the fine fragments of dust will often be nearly as great as that of the pebbles and lapilli largely mixed with it. Unless, perhaps, in the case of single outbursts of enormous violence, such as those of the Vesuvian eruption of 1822, the direction of fragmentary projection is never completely vertical. Whether by the more or less slightly oblique direction of the aperture or throat at the bottom of the funnel, or by an oblique direction being given to the gushes of steam from it by irregularities in the obstructions produced by matter in the bottom of the crater, or by the pressure of wind upon the ascending steam column itself, the direction of projection almost always varies more or less from the truly vertical, so that even when there is no sensible wind, the heavier fragments are found to fall principally towards one side of the crater and cone. The trajectory described, therefore, by the projected mass, considered as a whole, approaches to that of a parabola, or rather to innumerable parabolas described within the horizontal section of the whole cloud. When the mixed mass, as a whole, reaches its highest point or vertex of the parabola, the movement of descent commences the sorting of the mass in reference to the sizes of the mixed fragments.

Any large stones or fragments, being shot much higher than the highest point of the mixed mass, are seen to emerge out of it and above it. The lapilli and pebbles, descending for a considerable distance, if not to the surface (dependent upon their sizes in the parabolic path), force more or less before them downwards the finer dusty particles whose ascent they had before accelerated; but the finer particles rapidly acquiring a terminal velocity, remain suspended in the air in the neighbourhood of the place where the lapilli have separated themselves by their greater mass, if the air be quite still. But in the event of there being a wind, the finer particles no longer move in a

trajectory or curved path, but float and are carried away laterally in right-line paths, more or less oblique, to the horizon, and therefore to greater or less distances. If, however, a wind, and notably one of considerable velocity, exist prior to the projection of the entire mixed mass, the mean trajectory of the whole mass is altered and forced off to leeward, and it may be demonstrated that in such case the mean trajectory will be a parabola whose axis is no longer *quam proxime* vertical, but is tilted obliquely to leeward, through an angle whose angular measurement is to 90° as the horizontal velocity of the wind is to the vertical velocity of projection. The effect then of what has preceded may be illustrated by the diagram, Plate viii., where the parabola $a b c$, in dotted lines, is the mean path in still air. The angle $v a o$ represents the horizontal velocity of the wind as compared with that of projection, and $a d e$ the mean trajectory as resulting from the lateral effort of the wind. Large stones rising beyond the general mass, and going farther in horizontal range, will have trajectories of their own, such as $a x$, and will reach the ground a good deal beyond the range of any of the other particles in the mass. Some of the larger pebbles or lapilli will continue their parabolic descent, but the great mass of the pulverulent or finely divided matter, having acquired a terminal velocity soon after having reached the descending curve of the mean trajectory, will separate and descend slowly while floating off to leeward in paths similar to $z g$.

If the mass of the smaller particles consist of fragments whose densities and sizes are nearly the same, then the path $t z$ may be taken to represent their mean path of slow descent, and the horizontal distance to which a preponderant proportion of the entire shall be carried before it reaches the ground at g . At this point, supposing the ground to be a plane and level surface, the projected mass of fine material will be deposited as a low umbo or shallow mound at g , deepest towards the centre, and becoming evanescent round its curved circumference, which may approach the form of a circle or oval. We are thus enabled to see that in one, or in many successive ejections of such comminuted material, the conditions of projection being the same or nearly so, a very large proportion of the finer material projected will be carried to the same distance from the crater, and will, while the wind continues unaltered, be deposited upon the earth's surface at or in the close neighbourhood of the same spot. These circumstances will be most effectively and regularly fulfilled where the material blown up out of the crater is largest in mass, and is projected by one powerful gush of steam, issuing from a single adjutage situated about the middle of the crater cavity, or where several such take place in succession; and such have been usually the conditions under which such projections, during the times of modern observation at least, have been sent forth by Vesuvius, and where in the same mass the lapilli are smaller as compared with the still finer material, the distance between e and g will be less, and may even become so small that lapilli and dust are found in the same mound, or

in different portions of it. We may, therefore, not unwarrantably conclude that such were also the conditions under which the pulverulent matter which buried Pompei was belched forth in the year A. D. 79.

The condition under which projections of discrete material occasionally take place from Vesuvius, and no doubt from other volcanoes, are not always precisely such as have been described, and the circumstances wherein they differ give rise to some very curious phenomena, which are worthy of notice before proceeding further. From 1857, and for about three years afterwards, a secondary crater (or *bocca*, as such apertures are usually termed by Italians) had opened and remained so upon the northern side of the main crater of Vesuvius, and upon the slope not far down from the summit. This *bocca* was in 1858 a nearly circular aperture of from fifty to sixty feet in diameter, perforating at the surface right through the solid beds of lava, which at different periods had overflowed at that side from the main crater, and, descending far below these, passed, no doubt, through a succession of beds of conglomerates, loose lapilli, and probably thin lava sheets, in a direction tolerably vertical, so far as could be seen or judged of by the direction in which ejecta were blown out from it. The edges of this crater, being of solidified lava, enabled one to approach, though not without some danger, almost to the edge of the fiery abyss, the sides of which, even in daylight, were red-hot to within a few feet of the lip. The aperture opened upon a slope, by getting to the higher side of which, and cautiously approaching the edge, with the face and head enveloped in a wetted towel, it was possible for a few moments to look into the interior, and to see that its sides, though nearly perpendicular, were abrupt, craggy, and more or less undercut, and to hear above the rhythmical roar of the immense volume of superheated steam which was continually emitted in gushes from the mouth, the stifled, bubbling sound of gases and vapours, as if driven through some viscous liquid or obstructing discontinuous matter far below. The steam which escaped with considerable elastic force, filling the entire area of the *bocca*, was so highly superheated that it remained almost transparent for many feet above the lip, so transparent at the level of the latter that the fluttering image of a person standing a few feet off from one edge could be discerned by an observer standing on the opposite one. Rounded stones up to four or five inches in diameter were occasionally shot from this mouth, but its chief discharges of solid matter consisted of small pebbles, lapilli and fine comminuted volcanic dust, all of which were occasionally shot forth in somewhat large quantity. While this *bocca* continued open and free, the main crater was almost quiescent, its funnel-shaped cavity, from which dense vapours and steam constantly escaped, rather by permeating the entire mass of perfectly loose pulverulent material which filled the interior, leaving a large conoidal cavity above them, than by any apparent definite throat or aperture at the bottom, so far as could be ascertained by observations made around the brim, the loose material below which,

forming the funnel-shaped cavity, was too loose and soft to admit of being walked upon at all without danger of sinking into the mass, the temperature of which was high enough to scald; flakes of very viscous lava were, however, occasionally thrown out from the bottom of this crater. It was to take advantage of the peculiar character of this *bocca* that I prepared in 1859 all the apparatus and instruments necessary for ascertaining its temperature down to the greatest depth at which it might be possible to lower an instrument by means of a wire cord, suspended from the middle of a wire rope, held like the chain of a suspension bridge across the mouth of the *bocca*. The greater part of this apparatus remains still, through the kindness of Professor Guiscardi, in the care of the University of Naples, and may possibly be available for some future observer.

The *bocca* itself, however, suddenly and unexpectedly fell in, and all its peculiar features disappeared in a chaotic hollow of blocks of lava, and heaped-up incoherent material, before circumstances admitted of my return to Naples for the above purpose, a circumstance which is worthy of note as indicating that the pebbles, lapilli, and finer material which it discharged were derived from the under-cutting and shedding in of the imperfectly cohering beds constituting more or less of the sides at various and considerable depths, which, being undermined, at last produced the collapse of the *bocca*, that being perhaps also aided by other movements or erosions connected with the main crater. As the lapilli and pebbles discharged by this aperture appeared quite as much rounded—indeed, differed no way in character from those at previous periods discharged by the main crater—and as in this minor crater there was certainly no great accumulation of discontinuous material at the bottom continually being blown out, and falling back again, and in continual movement so as to get rounded there by attrition, so it appears to be a reasonable deduction that the rounded fragments driven out from the *bocca* were shed into it from the sides in an already rounded state, being, in fact, derived from the beds constituting the cone itself, all of which had been at some time or another previously shot forth from the main crater. For a long period during the year 1858, the pebbles and lapilli driven up from this mouth ascended to a considerable height, and formed rings in the air of a very curious character and singular appearance. It has long been known that smoke or vapour, when forcibly expelled from a cylindrical tube, occasionally takes the ring form. This was first, I believe, noticed in the smoke of smooth-bored artillery when fired in perfectly still air, the plane of the smoke rings being in that case at first perpendicular to the axis of the piece; they have been frequently observed in calm weather amongst the discharges from the funnels of locomotives, and I am informed are readily produced in the smoke from a tobacco pipe; and I once observed steam rings produced on a large scale, and in a very striking manner, by the discharges of a very large and old high-pressure blowing engine, which discharged through an iron cylindric funnel of four or five feet in

diameter. The rings in this case were at first in a horizontal plane, and gradually increased in diameter, as they all do, while floating off with the wind. Six or seven rings of various sizes, and in various stages of dissolution by condensation, could sometimes be counted together in the air; and on the occasion when I witnessed them, a nearly calm and moonlight autumn night, the effect of these illuminated halos, like those which the old painters imagined round the heads of their saints, was at once spectral and beautiful. In all these cases these rings are formed of gas or vapour; but in the case of those observed by me in 1858, sent forth from this *bocca*, the rings were composed of steam, and to a very large extent of the pulverulent material shot up by the steam from the *bocca*. At each discharge an opaque and horizontally somewhat flattened, but irregular, cloud was driven up to a height which I estimated to reach from 500 to 800 feet above the mouth. As its upward movement slackened, the cloud became more symmetric and circular in form: a clear space showed itself towards the centre, which rapidly enlarged as did the external diameter of the cloud, which very rapidly assumed the form of an almost perfect ring, curviform in section, but not of perfectly uniform thickness, some parts being generally denser and more opaque than others. The wind during the time of my observation was almost always from some southerly point, and these rings, constantly enlarging in diameter, though with much slowness after the first few moments, floated off to leeward over Somma and the plain beyond it, each ring, becoming gradually distorted, by gently ascending currents of air in its path, and the plane of the ring often becoming twisted and tilted from the horizontal direction which they had when first started. These rings were best observed with a good telescope, from eminences on the eastern side of the city of Naples, and, watching them steadily from thence, it could be distinctly seen that each ring, at the time its upward movement was arrested, consisted of fragments of solid matter differing considerably in size, and that these, as the ring formed and became symmetric, had a gyratory or circular movement in nearly vertical and radial planes, the rotation being outwards at the top part of the ring and inwards or towards the centre at the lower part. The larger and heavier fragments, however, began rapidly to separate themselves, and to rain as it were out of the ring, so as to present a sort of ring-shaped beard falling from the lower side, denser and thicker in some places than others, but remaining with the ring as both were driven along by the wind. As the plane of the ring became enlarged, attenuated, distorted, and altered by tilting, and finally disappeared, leaving only a trace of dust cloud in the air, so did the bearded columns of lapilli that rained out of the ring, at first in nearly right lines, slightly oblique to the vertical, gradually become curved more oblique, distorted, and scattered, until, long before the fragments appeared to have reached the ground, they ceased to be visible at all. These ring clouds of dust and pebbles, when first formed at the termination of their ascent, were not, as I estimated, very much

larger in diameter than the mouth of the *bocca* whence they came, but some of them remained still recognisable as fragmentary or distorted rings until they had attained apparently six or eight times that diameter, or one by estimation of from 300 to 400 feet, and before finally disappearing many of them seemed to have floated to a horizontal distance equal to that from the *bocca* to beyond where the northern slopes of Somma joined the plain. I am informed that rings like these have since been described as observed above Vesuvius, though I do not know by whom or where the account has been given of them. In a physical point of view, the mechanism of their production, whether of vapour and smoke only, or of vapour, and in great part of solid matter, much of which was in fragments by no means minute, is of much interest. The point which connects them with our present subject is that they present an example of the great distance to which discrete material may be carried from volcanic vents by the wind, though the height of projection be but moderate, by a mechanism which is in some respects entirely different from that which has been already described.

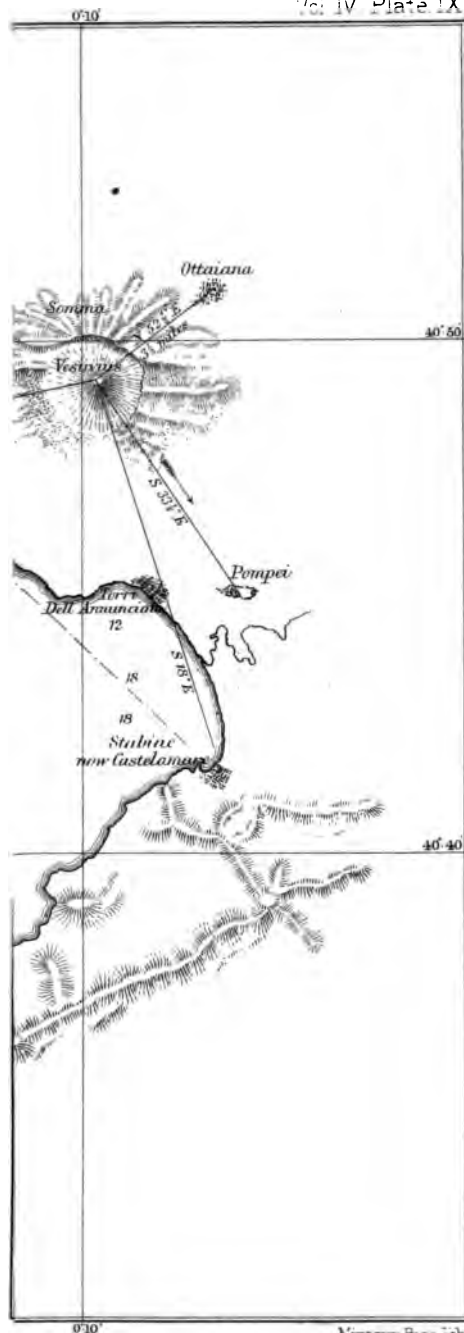
The only contemporary account of the circumstances attending the overwhelming of Pompei which has come down to us, is that contained in the celebrated and often quoted letter of Pliny the younger to Tacitus, in which he gives account of the proceedings of his uncle Pliny the naturalist, on the day, or on one of the days, of the eruption, and of his death at the house of Pomponianus, situated close by the sea at Stabiae, near the present Castellamare. This letter, however, really contains scarcely any description of the eruption, and but very few facts which are of any physical value in assisting us by references to such natural observations as can still be made in deciphering the actual circumstances under which Pompei was overwhelmed.

The letter, too, is misleading in some respects by the want of power shown by all classical authors to interpret with certainty or truth natural phenomena, of the laws governing which they understood so little. The often ill-founded conclusions of antiquarians, from facts which they supposed they had observed, during times before archæology had assumed anything of its present exactness and scientific character, have further tended to confuse the notions which have become prevalent as to the nature of this catastrophe. Thus, from the statement of Pliny's letter, that his uncle's death, after he had commenced his attempt to escape from the house of Pomponianus, was occasioned by some suffocating vapour which suddenly surrounded the spot on which he lay, has given rise to the fanciful notion that eruptive rents suddenly burst through the plain not far from the place where Pliny the elder lay; and some Italian writers of the last century imagined on this assumption that Pompei was buried by eruptions breaking through the plain itself, or at the base of Vesuvius close by. Nothing can be more probable than that a huge cloud of steam and sulphurous or hydrochloric acid gases, the ordinary products of every eruption, may have eddied down from the crater and been

driven by the wind across the plain and over against Stabiae, and that, by the inhalation of one of these mixed with much fine dust, Pliny, who was a corpulent and puffy man, with weak lungs, was sufficiently choked to produce asphyxia and his death. The statement also of this letter, that the chariots which had been ordered out from the house of Pomponianus could not be kept steady, but rolled backwards and forwards, though some stones were put under the wheels, has been adduced in proof of assumed enormous earthquake oscillations of the ground near Stabiae by the violence of the eruption; but admitting the fact, it really proves nothing as to the extent of earthquake oscillation at the spot, which could not have been great, or the house of Pomponianus, from which Pliny had just escaped, must have been levelled, as indeed must *a fortiori* have been those of Pompei itself, which are still standing, although it may be alleged, as respects the latter, that they were *possibly* propped up previously to the time of Pliny's death by the dust which had already partially overwhelmed the city. Much learned speculation has also been wasted upon questions connected with the supposed upheaval of the plain upon which Pompei stands, and upon the Sarno, now an insignificant stream, though a torrent during continuous heavy rain, being but the residue of a large navigable estuary that led up to Pompei itself, where the discovery of some architectural remains, supposed to be a water-gate, and the finding occasionally in the soil of the plain a few shells of existing Mediterranean species, which may have been blown in by the wind or carried there by human beings, seem to be the only foundations on which that speculation has been based. That the plain at its eastern side has not been upheaved to any appreciable extent since the foundation of Stabiae appears certain, or otherwise the remains of Stabiae and Castellamare, the naval dockyard of modern Naples, could not remain as they do, close by the margin and very near the sea level. So, also, at the other or western side of the plain, the level of the main street of Pompei which has been cleared out is nowhere more than about twenty-seven feet above the level of the sea; there is, therefore, little evidence or even room for the supposition of bodily upheaval at this side, or indeed, of any part of the plain, and, as the limestone formation of the great peninsula between Sorrento and Amalfi in all probability underlies the plain of the Sarno, over which the ejections for ages of Somma and Vesuvius have been spread, any such bodily elevation could scarcely take place unless it comprehended the whole of the limestone formations of that peninsula, of which I am not aware that proof exists. The catchment or gathering area of the Sarno, about 150 square English miles, is quite too small for it ever to have been a great river with a navigable estuary, unless on the supposition of enormous changes having taken place since the foundation of Pompei, in the surface, levels, and natural features of the Terra de Lavoro to the northwards. The sea at that period was, no doubt, nearer to Pompei, and there may have been some small estuary of the Sarno which once, though long before our era, permitted small

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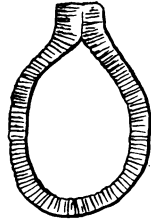
boats to reach Pompei, though the configurations of the beach between Torre dell' Annunciata and Castell' amare, which is one great unbroken sweep, present no indication of its ever having been pierced by such an estuary. The plain of the Sarno has been gradually filled and silted up to its present level, as it seems to me, by the various ejecta from Somma and Vesuvius, of their washing down by rain, and by the tufaceous muds brought down by the Sarno itself; and it seems most reasonable to conclude that the features of the whole plain were in A.D. 79 very much the same as they are now, and that base Pompei stood at very nearly, if not exactly, the same level then as it does now.

Amongst the few facts recorded in the letter of Pliny the younger which have any significance in interpreting the conditions under which Pompei was overwhelmed, are, first—the indications which may be gathered from it as to the direction of the wind. A Roman fleet under the command of Pliny the elder lay at anchor at the time the eruption commenced, at the port of Miseno, near the cape of that name, where Pliny himself was staying. Pliny, informed by his sister-in-law, Plinia, that a very singular cloud was visible to the eastward, ordered a light vessel (one probably not very different from a modern "speronala") to be got ready to take him across the bay for a nearer inspection of the phenomenon. The sea at this time could not have been rough, or Pliny would scarcely have proposed to cross it in such a vessel, nor could the wind have been in a direction much opposed to his proposed passage across the bay. Before he embarked, however, a message reached him from Rectina, the wife of Bassus, who had a villa near the sea, somewhere on the south-west slope of Vesuvius, and situated probably between Resina and Herculaneum, near and over which Torre del Grecco now stands, entreating him to come to her help, as she was in great danger from the ejecta thrown down from the mountain, and could only safely escape by sea. Pliny, therefore, ordered out some large vessels or galleys, and shaped a course towards Herculaneum, but was unable to land, or apparently to offer any assistance in consequence of the volcanic ejecta which fell upon his ship. He, therefore, directed his pilot to shape a course for Stabiae, and land him at the house of Pomponianus, which he seems to have reached without difficulty. His course from Miseno to Herculaneum was, therefore, nearly from west to east, and the continuation of his voyage from Herculaneum to Stabiae nearly south-east, or more exactly E. 44° S. from the former, as may be seen on the map, Plate ix.

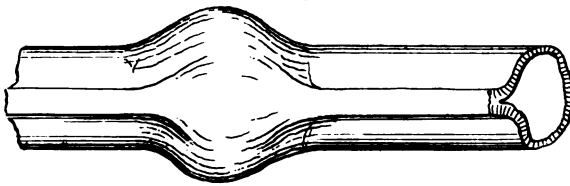
The sea had risen apparently as well as the wind during the voyage, both being boisterous when he arrived at Stabiae. We may conclude, therefore, that the direction of the wind was from the westward within some few points to the north or south of it; but more probably a little from the northward than from the south, as the galleys which brought him to Stabiae seemed to have been unable to remain there. The sudden rising of the violent wind is a phenomenon well known to accompany every great eruption, and the wind gave rise to the

heavy sea, and not any earthquake rocking of the sea bottom as has been often inferred by older authors.

Now, Pompei bears from the existing crater of Vesuvius a direction S. $33\frac{1}{2}^{\circ}$ E., distant $6\frac{1}{2}$ miles, and Stabiae bears S. 18° E., distant $10\frac{1}{2}$ miles from the same crater, so that if the direction of the wind was exactly that of Pliny's course after leaving Herculaneum, it did not differ more than 12° from blowing straight over Pompei from the Vesuvian crater, nor from Stabiae more than 28° . The wind, therefore, was in such a direction as would bring fine ejected material right over Pompei, and, allowing for the dispersion by greater distance of the heavier ejecta, is there any difficulty in seeing how these reached Stabiae where, according to Pliny's letter, the courtyard of the house of Pomponianus became gradually blocked up, not with dust and lapilli, but with stones and pebbles. We have, however, no certain knowledge that the wind was *precisely* aft of Pliny's course after leaving Herculaneum, though it cannot have differed much from that direction, judging from the time that the galleys must have reached Herculaneum. We are, therefore, justified in concluding that the true direction of the wind during the first night and day of the eruption was straight over Pompei from the crater, or in the direction S. $33\frac{1}{2}^{\circ}$ E., which only differs by $15\frac{1}{2}^{\circ}$ from the direction of Stabiae from the same crater. We may, therefore, take the testimony presented by the immense mound of dust which covered Pompei as giving the true direction of the wind during all the earlier hours of the eruption, and that the stones and larger fragments having greater trajectories which reached Stabiae were projected with it in the many successive explosions. The difficulty which will suggest itself to the reader of why these larger fragments should have differed at all in direction from the course taken by Pompeian dust, is far more apparent than real; for, 1. We have no other land-mark by which to fix the direction taken by these heavier fragments than Stabiae, and although they fell here, vast, and for aught we know still larger, quantities may have fallen also to the north and east of Stabiae for a distance of from two to three miles, which would bring the north-eastern extremity into the line passing through Pompei and the crater. 2. It seems extremely probable that during the latter period of the day on which Pliny perished, the violent wind in a S.S.E. direction, sweeping over the plain, eddying round the northern base of Vesuvius or Somma, and impinging obliquely upon the face of the precipitous mountains of the Sorrento Peninsula, would be deflected towards the S.W., and so carry the heavier projectiles in the lower part of their course a little to the S. and W. 3. It is possible that the direction of the wind, after the deposit of a large portion of the dust which overwhelmed Pompei, may have changed by a point or two more to the southward, and so carried the larger fragments which reached Stabiae later in the day a little more to the southward. Lastly, the analogy of almost all great eruptions justifies us in concluding that the whole of the ejecta may not have been projected from the crater itself in precisely the same direction.

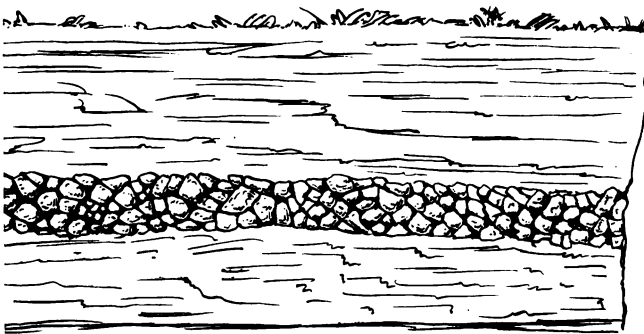


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4.

As we walk over the surface of the material that covers still by far the larger part of the ancient city beneath our feet, we are struck by the fact that the general contour is that of a low irregular *umbo*, a *colline* sloping off into the plain, but sloping less in the direction of the base of Vesuvius at its junction with the plain, the *umbo* being thus, as it were, joined to the roof of the mountain by a sort of low, flat, peninsular rise of ground, above the surrounding level. This would have been the shape that, on principles already enunciated, must have been assumed by the deposit of pulverulent matter, whether due to a single or to many successive ejections, if the deposit had taken place about the same surface upon a perfectly flat plain. When, however, we pass round the disinterred walls of the city, and traverse those of its streets which have been cleared of rubbish, we see that the ancient city itself was built upon a low and irregular piece of ground, sloping off from it differently at different sides; the rise of the ground towards the north-west, south-east, and southern sides being the steepest, so that the *umbo*-like form assumed by the deposited matter was rendered more convex by the shape of the ground upon which the city was built. It appears, therefore, that the site chosen for the city, as a commanding one and secure from inundation, was upon a boss or elevation formed by one of the extremely ancient outflows from the crater of Somma, consisting chiefly of solidified, though probably cavernous and irregularly broken-up, rocky material, which, as is almost always the case in lava streams, after flowing down a steep slope, have, on reaching the plain, bulged out into large flattened masses where their movement has been arrested. This deeper foundation of Pompei has, like the lava stream which originated it, been covered up in the course of ages by deposits of loose or comminuted material. It is evident that there are beds of lava below the city which even now, or, if not now, at the time of the heaping on of the shower of lapilli and dust, are or were being locally broken and crushed down, and the *boccas* and hollow places compacted together by gravity. For in no other way can the local distortion of levels of the houses, of lines originally horizontal, the fall of arched lintels, the distortions in level of the impluvia, and of the door sills, and the sills of the shutters of shops, be accounted for. I observed and sketched some of these distorted sills, one remarkable case being shown in Plate x., fig. 3, where the arched lintel over the shop front, and part of the piers at either side had fallen, both the piers being slightly out of plumb, and a little nearer to each other at and near the base than near their tops. The same lateral force which had disturbed these by its "end on" pressure, had forced the sill stones *a*, *b*, *c*, which contained the shutter groove for closing the shop, and which must have been originally level and straight, into the positions shown in the diagram. The abutting ends of the two most inclined stones, *a* and *b*, having been urged against each other with such force as to have slightly crumbled the stones and splintered their lower arrises.

No subterraneous movements, as it appears to me, can account for

such powerful lateral disturbances varying in character within short distances, except local subsidences produced at considerable depths below the street levels by the breaking in of local hollows beneath, producing lateral movements in some cases, as above, of compression, and in others of extension, as evidenced by numerous wall fissures widest at the bottom, and narrowing towards the top. The weight of material deposited upon Pompei was, in the aggregate, enormous, although it must be borne in mind that the depth of deposit, which in the year 79 rendered the city uninhabitable, was probably very much less than that which now covers the unexcavated city. Eighteen hundred years have passed away since then, and innumerable eruptions, great and small, have since the year 79 shed their *debris* over the heap then formed, and added to its depth, which now is, probably, in some places 40 or 50 feet. We have some, though not perhaps very certain, data for assigning the depth of material which may have covered the city just before its final abandonment. Bearing in mind that the shower of pulverulent matter must have continued for many hours, if not for days, in an irregular, intermittent manner, sometimes dense to suffocation, at others comparatively rare, as the belches from the crater were greater or less, or the wind at the city shuffled or shifted for the moment, there was ample time for the escape of the inhabitants, and for their carrying off their most precious effects. And as even three or four feet in depth in the streets would have rendered escape difficult, it seems reasonable to conclude that the inhabitants had escaped before two yards in depth of material had fallen over the city generally. The depth, however, must have varied considerably in different places, for, like snow or hail, and all other light material descending through the air, the dust or ashes must have been heaped up in drifts in many of the streets and places presenting suitable directions to that of the wind.

The final destruction of the city, however, took place when the buildings began to fall beneath the mass deposited upon them.

By far the largest proportion of the Pompeian buildings were only of one storey in height, a few only, and those of the meaner class of dwellings, chiefly situated above shops, had a second storey, indicated by some vestige of stair-cases. The higher class of dwellings appear to have had timber roofs covered with tiles, with but a slight slope towards the open court which usually formed the centre of the dwelling; these, though supported by columns near the eaves, would bear but a slender load before breaking down. The great majority of the houses, however, the lineal ancestors of those which at the present day we find at Lacava, Vietri, and many other of the ancient towns of the extreme south of Italy, and in Sicily, were flat-roofed. Even the construction of the shops now in use at Lacava is identical with those disinterred at Pompei. Although little is known as to what was the actual construction of the middle class and meaner houses of Pompei, we may rationally conclude that they were structurally the same as those of the light class of modern houses in

the old towns above mentioned, and that of the flat terrace roofs which are still prevalent in the Lipari Islands, where customs have changed but little, for perhaps thousands of years. The roofs of Pompei consisted of a layer of rough beams, often but rudely squared, and of no great size, placed upon the walls at distances of three to five feet apart, covered over by rough oak planking, and surmounted by from six to nine inches in thickness of a beton consisting of lime, pebbles, or broken stone, and volcanic sand or pozzuolano. Flat roofs thus constructed, having in view the average spans of unsupported beams, would probably be broken down by a uniformly distributed load of much less than half a ton to the square foot. Adopting that maximum limit, and assuming the weight of deposited material to have been not less than one hundred pounds per cubic foot, we see that a deposit of between eleven and twelve feet in depth must have been enough to have originated the destruction of the houses, the forcing down of the roofs of which must have prised and dislocated the walls to a large extent. Perhaps the average thickness of deposit which covered the city in A.D. 79 may have much exceeded the minimum thus assumed, but that its depth was nothing approaching that which now covers the unexcavated portions of the city seems indicated by two facts. It was found during the latter part of the last century that in one instance at least a place where treasure had been deposited was marked, and by excavation down to its place had been at some remote period removed, a feat scarcely likely to have been performed through any great depth of loose material. The quantity of timber which, so far as I am aware, has been dug out, bears no proportion to the very large quantity which must have entered into the roofs of the inhabited city, nor have any considerable quantities of charcoal, or of "humus," resulting from the wet decay of timber been found. I therefore hazard the conjecture that for a century or more after A.D. 79, the depth of loose material covering the city was not such as to prevent the inhabitants of the neighbourhood from extracting a large proportion of the timber that had been buried, and employing it for structural uses, or for fuel. If this be admitted, it follows that since the inhumation of the city, and during the eighteen hundred years that have since elapsed, a mass of pulverulent matter has been gradually shed over its site by Vesuvius, nearly equal in depth to that which in the great eruption of A.D. 79 covered it; and if so there is no geological difficulty in admitting that the plain of the Sarno, as well as the country all round Vesuvius, has been considerably raised in level by volcanic deposition, and without any general movement of subterraneous elevation. On the same grounds we see the high probability there is, that the sea shore was at the time of the foundation of Pompei, and for many centuries afterwards, considerably nearer the city than it now is. Indeed, the land all round Vesuvius has been long steadily encroaching upon the sea, for along its seaward slope ejecta or lava from the mountain have repeatedly reached and even run into the sea, and the production of shoals has mainly been

prevented by the rapid slope of the sea bottom, and the depth of water under the mountain. Even assuming, as above, the depth of dusty deposit at the time of the abandonment of the city did not exceed one-half its present depth of covering, a difficulty may occur to some whether so enormous a mass as even 20 feet in general depth could have been blown from the volcanic cone of Somma, then destroyed, within the period of probably not more than three or four days. The dusty deposit, upon the principles already enunciated, must have been of unequal thickness deepest towards the centre, and thinning off towards the edges or circumference. The ancient city—judging from the area within the walls, and allowing for suburbs outside these, extending about as far in all directions as they have been found to do in the part excavated in the neighbourhood of the Street of Tombs, to the north-west of the city—would cover an area of scarcely a mile in diameter, for the city within the walls was scarcely a mile in its greatest length, viz. : from north-west to south-east, and scarcely half-a-mile in width, transverse to this. To cover the area of a circle one mile in diameter uniformly to a depth of seven yards or twenty-one feet requires rather less than 17,000,000 of cubic yards of material, and such a mass would probably have been quite sufficient to inter the whole city. The existing cone of Vesuvius, down to the level of the Hermitage which is several feet below the level of the Atria del Cavallo, has been calculated by me as having a volume of 0.446 of a cubic mile (Phil. Trans., 1873), and the cone of Somma, prior to A. D. 79, may probably have been of much larger volume, but, taking it to have been the same as now, then the blown away portion of it which covered Pompei was only $\frac{1}{148}$ of the entire mass of the ablated cone, and, indeed, may have borne a far less proportion, for much of the blown off dust may have been heaved up from far greater depths, leaving cavities into which large fragments of the destroyed cone subsided. That Pompei was covered up by the deposit of successive dense clouds of dust and lapilli carried by the wind does not seem to have entered the mind of Sir. W. Hamilton, who appears to have considered the mass to have been in some way due to projectile forces only, and, in illustration of the sufficiency of this, observes that he found a lump of pumice of eight pounds in weight, either on the surface, or buried in the dusty material. It is not impossible that some large fragments of a material so light as pumice may have become entangled and swept along with the dust cloud, though the fact is by no means probable. I hunted in vain for large fragments of pumice or denser material, and was unable to find a single piece, even of pumice, weighing more than a few ounces, so embedded that it could not but have been carried with the finer material. Large fragments may have been actually projected and deposited in the higher strata in eruptions occurring long after A. D. 79; but it seems more probable that the large fragment referred to by Hamilton may have been forced out of some of the walls or buildings in the city, and never thrown over the latter at all. In support of this pro-

bility, I observed in a bank of pulverulent material, not far from the amphitheatre, a bed, several feet in length, and about fifteen inches deep, exposed, which at first glance looked like blocks of pumice of ten, twenty, or twenty-five pounds weight, but a closer examination showed that they were lumps of travertine carried out and forced away from the rubble wall of some overthrown building, as shown in Plate x., fig. 4. Some such origin was probably that of Hamilton's eight-pound block, for a mass of such a weight, as well as those of the bed of travertine, must, if projected along with the dust cloud, have gone much farther and fallen beyond its limits, as did the heavier fragments which fell over Stabiae.

A good deal of obscurity and error as to the nature of the deposit has also been produced by the speculations of archæologists and others as to supposed *illuviones*, or torrents of mud, imagined to have been belched forth and run like lava over the city. Of the existence of such I could find no traces. Had the city been buried in such a manner it is scarcely conceivable but that immense remains of these mud currents must have been found covering the low elevation or peninsula which joins the site of the city to the foot of the mountain; and probably even now traces would exist on the flank of Vesuvius in the track of such masses, had they ever descended, and that such masses of mud could ever have been blown into the air and dropped upon the city is too absurd for consideration. The notion of these mud deposits has arisen, first, from the absence of any clear conception of the mechanism here attempted to be developed, by which immense dust clouds are projected and wind-carried; and from a very imperfect and partial examination, without intelligent analysis of the circumstances under which some not inconsiderable portions of the dusty covering of Pompei have been subsequently wetted and converted into mud, which in some cases has flowed into cellars or other hollows. So far as a careful examination enabled me to judge, these partial productions of mud were due to accidental saturations of the previously dry dusty material by overflows of water consequent upon the destruction of the city. That Pompei was well supplied with water is evident from the water-pipes that have been found beneath the streets and buildings, by the existence of water-cocks or taps in the houses, and by the existence of trades, such as those of fullers and dyers, requiring copious supplies of water, as well as by public fountains and baths. When the city became buried some of these water supplies must have overflowed and continued running, until, at length, choked in the wetted volcanic paste which the water created around them, and the recession of which by drains or gullies must have been greatly impeded. This appears to be the real origin of the running mud which filled up some of the large cellars and other hollows, and the only foundation for the untenable notion of *illuviones*, or mud eruptions, having covered the city. Mud ejections, it may be remarked, have never been recorded upon any assured authority as having issued from either Vesuvius or Etna. That the dusty material which fell upon Pompei was in part damped by

the condensed steam, and rain resulting from that, which were blown up and descended along with the dry material, is certain, not only from the phenomena generally observed in eruptions like this, but proved by the many scattered beds of "spherulites," or pisolites, or little balls of coherent dust which are found in many places in the covering deposit. These little coherent balls, which vary in size from that of a very large to a very small pea, are found in great abundance in the neighbourhood of the Amphitheatre, that is, about the portion of the deposit most distant from the crater, and which would, therefore, be likely to have the largest amount of diffused moisture mixed with it. These spherulites have not much coherence: they can be readily crushed between the finger and thumb, and have obviously been formed by the aggregation of very small moist particles descending through the air from a considerable height, and increasing in size as they descended, much in the same way as hailstones are formed by the aggregation of minute icy spiculae descending from the clouds. These little concretionary nodules show no well-marked internal structure: they are mere aggregates of very fine dust of nearly uniform size. If, however, the beds in which they are now surrounded and preserved were saturated with calcareous water for a sufficient length of time, there is little doubt that the pisolites would be converted into concretions like those of oolitic beds by the formation of crystals of arragonite, arranged radially to the centre of each sphere. Unless, however, in such low-lying portions of the city within the walls as may have had their surface drainage imperviously cut off, it does not seem likely that rain water alone could have been sufficient to have thoroughly saturated and reduced to mud any large portion of the dry and thirsty dust that covered up the city. Another old notion that the mud currents were produced by an earthquake wave of translation which in A.D. 79, or subsequently, came in from the sea and swept over the buried city, seems devoid of any probability, first, because there is no proof that any earthquake has ever occurred off the coasts of Italy of sufficient power to produce such a wave, that which overwhelmed the mole of Miseno(?) or Messina(?), having been produced by a great landslip under water from the opposite coast of Calabria, being no exception; secondly, because the streets of Pompei being from 25 to perhaps about 30 feet above the level of the sea, a wave which could have swept over the city would have exceeded in dimensions those which occur in South America, and must have prodigiously disturbed and left its traces upon the incoherent matter which covered the city.

A few remarks may be made as to the probable temperature of the pulverulent mass at the time when it was first showered over the city. A notion very commonly to be found in the older Italian and other authors, and one which, indeed, has been adopted by both painters and novelists, has been that the dusty material as well as the heavy stones with which they erroneously assumed it to have been mixed, were at a very high temperature, if not red-hot, when they reached

the city. And Sir William Hamilton, in recording the eruption of 1779, which showered many heavy and ignited masses over the town of Ottaiano, seems to imply that such may have been his view as to Pompei; for, having described the setting on fire and destruction of several of the buildings of the town by these hot projectiles, he infers that, had the eruption been of long continuance, Ottaiano must have suffered the fate of Pompei. That the material must have reached Pompei at a temperature a good deal above the atmosphere does not appear to admit of much doubt. The dust and lapilli driven forth from any active crater are, at the instant of ejection, at or but little below a red heat. Each individual small particle, if driven alone through many hundred feet of air, would, no doubt, be completely cooled. But the dust is driven forth as a cloud, so dense as to be absolutely opaque when its thickness is reduced to even a thickness of a few inches, as in the case of the dust rings already described. It is, moreover, pushed upwards by the head of an issuing column of superheated steam, through which the particles begin their descent. As the outer surface of the dust-cloud bears at first but a small proportion to its volume, and as there is but little time occupied in the ascent, so it may be concluded that no very great cooling takes place until after the cloud has reached its highest elevation. The particles begin to descend through an atmosphere mingled with steam, portions of which are condensing into water; and, bearing in mind that every pound of steam, without reference to its being superheated, evolves, in condensing, 966 units of heat, it is plain that the dust-cloud, while high up, is not losing heat only, but also receiving it. At what temperature the dust-cloud may reach the earth we have not sufficient data to decide, and it will, in some degree, depend upon the total volume of the cloud, and the size of its particles; but where a large proportion of these are as large as lapilli usually are, the rate of descent of the whole being measured very much by that of the larger particles which force the smaller before them, so the time of descent, and, therefore, the loss of heat during it, may often not be very great. I conclude, therefore, that the dust which covered Pompei may have landed upon the city at a temperature hot enough, probably, to scald animal muscle, but not hot enough to set fire to wood. One circumstance noticed by me at Pompei may, perhaps, justify the conjecture that its temperature approached 250° or, perhaps, even 300° Fahrenheit. An old lead water-pipe, of the section and form shown in Plate x., figs. 5 and 6, had several feet of its length, from an extremity where it had been broken off, exposed to view, lying *in situ*, where it had been found embedded a few inches beneath the heavy pavement of trachyte which had formed the surface of the street, and which had been removed to get at the pipe. The pipe itself was of the oldest Roman form, produced by "burning," as it is called, together with melted and strongly heated lead, the two edges of a long plate of lead brought to touch each other by turning the plate into the tubular shape shown. This pipe has a more than usual technical interest

attached to it from the circumstance that the joint by which the length of pipe thus formed was united with the next adjoining length, as at *a*, was not made by "burning," which has been supposed the only method known to the Romans of uniting lead to lead, but is formed of solder, a white alloy of lead and tin, apparently such as is used by plumbers in modern days, the solder joint itself being what is called in that trade a "wiped" joint. The lead of this pipe was soft and sectile, as I found by cutting it with a knife, but the section where it is broken across shows that the metal is crystalline throughout, the long axes of the metallic crystals being everywhere almost exactly at right angles to the contour or surfaces of the pipe.

In some shallow, and nearly cylindrical, dyers' vats observed by me at no great distance from this pipe, the lead, which was of considerable thickness, was also crystallized in the same form.

Now, it is well known to metallurgists that, while lead as cast into sheets or other forms shows but little trace of crystallization, this state may be induced very rapidly by heating the metal to a temperature of about 300° Fahr., or to rather less than half-way towards its melting point. And if the temperature be maintained for a considerable time, this molecular change takes place at a much lower temperature, one probably not exceeding the boiling point of water. I conclude it as probable, therefore, that the dust which filled this street of Pompei fell at such a temperature as to have slowly transferred enough of heat to the ground, to the depth of some twelve or fifteen inches, as to have induced this crystallization in the pipe beneath the pavement, a not extravagant supposition if we remember that the mass, losing heat by conduction to the pavement, was many feet in depth. If this conclusion be admitted, it would seem to fix a superior and an inferior limit to the temperature of the mass which fell upon Pompei; it was as hot as about the boiling point of water, and it was not hot enough to melt lead or to fire the wood-work with which it came in contact; or, the temperature was somewhere between 200° and about 600° Fahr.

I am bound to remark, however, that this train of evidence is not absolutely conclusive, for a water-pipe, quite the same in its mode of manufacture as that here described, exists in the museum of the city of Marseilles, which is crystallized, though not with the same fulness of development, and which, it is stated, was dug up from one of the most ancient parts of Marseilles, thought to have been the site of the ancient city of Pytheas and Euthymenes; and there is no evidence that this pipe was ever exposed to a temperature higher than that of the atmosphere or the ground which covered it. The dyers' vats may possibly have owed their crystallization to the pouring into them of boiling liquids. It is, moreover, known that where gases or vapours are exhaled, capable of inceptive chemical combination with lead, crystallization is *sometimes* induced. Thus, some ancient lead coffins, which have been dug up from under cathedrals, have been

found more or less crystalline, the sheets of lead of which they were formed having been cast in times long anterior to the modern methods of making sheet lead by lamination.

A few remarks remain to be made upon the circumstances which appear to have attended the entombment of Herculaneum, and which, though occurring during the same eruption, seem to have differed essentially from those which attended the overwhelming of Pompei. These circumstances, as respects Herculaneum, are much more difficult to decipher than those of Pompei—partly because so very small a portion of this buried city has ever been exposed to even imperfect view; and partly because some of the most salient conclusions as to the nature of its interment have long remained stamped with the authority of Sir W. Hamilton, and his dicta repeated almost without question from author to author are undoubtedly wrong. These having been applied by later authorities, and in very opposite ways, to their interpretation in part of the conditions in which the celebrated papyrus rolls of Greek and Latin MSS. were here found, have issued in still further confusion. That Herculaneum was not overwhelmed by successive heavy clouds of volcanic dust projected and then carried by the wind, may be said to be certain, if we admit what has preceded with reference to Pompei; for, as Herculaneum bears from the crater of Vesuvius W. 13° S., distant about five miles, or in direction approximately orthogonal to that of the wind which carried the dust over Pompei, it is clear that, had clouds of discrete material been ejected at this southern side of the mountain, they must have been swept away towards the eastward, and deposited somewhere in that direction. There is great difficulty in examining with accuracy, and upon a sufficiently large scale, the mineral or lithological nature of the material, the lowermost strata of which have actually covered Herculaneum. It is both difficult and dangerous to thread the labyrinth of dark subterranean passages encumbered by buttresses supporting the ground above, which offer the only narrow field for observation. The excavated surfaces are very generally soiled or smoky, and in some cases glistening with percolating water; and the gloomy glimmer of candles or smoking torches renders observation extremely difficult. In 1864 I made as careful an examination, accompanied by my friend Professor Guiscardi, of the University of Naples, as these circumstances permitted, and the conclusion to which I was led was that the covering material was a volcanic conglomerate, consisting of various-sized fragments of volcanic material, pumice being largely interspersed with much more of comminuted matter having much the character of many of the tufa beds which are found intercalated in those forming the escarpment of Somma. In many instances the filling material has with great exactness adapted itself to the surfaces of the cavities it reached, but in others the filling seemed less perfect, and as if but little pressure of a hydrostatic character had forced it on. In what state was this material when first it reached the city is a question which it appears to me will need further researches, only possible by

the laying bare of larger portions of the buried ruins. That the favourite hypothesis of Sir Wm. Hamilton, adopted in an unquestioning manner by so many since, namely, that the covering conglomerate, whether issuing from the central crater or from a mouth opened on the south-western slope of the mountain, was ejected along with vast volumes of water, and already reduced to the state of liquid mud, in which condition it flowed down the flank of the mountain, and ran as a fluid into all the streets and open places of the city, appears devoid of any real basis. As has been already said, no such belchings forth of mud and water have ever been known in the two great European volcanoes; and Monte Nuovo, near Naples, which was thrown up in a few hours and with great violence, and which has been adduced as presenting some of the phenomena of mud eruption, seems to me wholly devoid of any such appearances, all the ejecta forming its cone appearing to have been violently shot forth as discrete material and at a high temperature. The fact upon which Sir Wm. Hamilton seems to have placed most reliance in support of his hypothesis of mud *illuviones* was that a perfect cast or mould was observed by him to have been formed by the filling material against the surfaces of an architectural stone mask forming part of the decorations of the proscenium of the theatre, but there is no force whatever in this supposed example. Such casts, even from the human body, were found at Pompei, where the dry dust subsequent to its deposition had become damped or wetted by infiltrated moisture. The cast from the mask referred to by Sir Wm. Hamilton would have been equally perfect if produced by dry powder of volcanic origin deposited upon it, and subsequently indurated by the infiltration of water with or without mineral matter in solution. Some objections, however, which have been urged against the physical possibilities of these mud currents appear to me to possess but little force. It has been urged that such mud streams, which must have been at least as hot as boiling water when first emitted, must have rapidly stiffened, and ceased to flow with anything like the liquidity with which their having reached Herculaneum, and other conditions of the cases, necessarily involve. If the material, however, when emitted, were of tolerably liquid mud, from the vastness of its mass and from the rapid slope of the mountain, it would have reached Herculaneum long before any considerable diminution of its plasticity or of its temperature could have taken place. But might not the whole of the lower strata of material which covered Herculaneum in A.D. 79—above which there is a vast depth of material said to present several distinct strata, and concluded with much probability to have been sent forth, as undoubtedly the upper portions of it have been, within the eighteen hundred years subsequent to the burial of the city—have been ejected in a solid and more or less discontinuous state, and, rolling down the south-western flank, reached the city in the state of finely divided running material possessing that mutual repulsion and intermobility of particles which is known to characterise all non-metallic powdering material at a tolerably high temperature, of

which hot sand is a familiar example? The ancient cone of the volcano suffered complete ablation in this eruption. There is no improbability in supposing that immense fragments of its south-western side, probably occupying positions not far from the base of the modern cone indicated by the "Piane," or abrupt change of slope still visible on this side of the mountain, may have been hurled over in a heated condition, and, rolling down the steep slope, and being continually comminuted in their headlong course, have reached Herculaneum in a state sufficiently small, when pushed on by like material from above and behind, to have flowed into and filled the streets and buildings of the city. In Pliny's letter it is expressly recorded that "vast fragments rolled down from the mountain and obstructed all the shore." The buildings have been ascertained to have been chiefly of one storey in height, and flat-roofed like those of Pompei, and must have been readily broken down by the flood of material of a density much greater than that of the dust of Pompei. If this view be adopted it remains to be explained how the mass came to assume the coherent form of a volcanic conglomerate which it now presents. This seems to present but little difficulty.

I have elsewhere shown that materials closely analogous to volcanic products, namely, the broken slags of iron smelting furnaces, when tipped into heaps of not many feet in depth, and exposed to ordinary rain and moisture, soon become a compact mass of conglomerate. In the present case the percolation of water, and the formation of stalactitic masses, which seem silicious as well as calcareous, at present found in many of the excavations, prove that the covering material, though now itself covered up and obstructed by seventy feet or more of other volcanic matter, is still percolated by water carrying more or less mineral matter along with it, though water alone acting upon the slightly deliquescent material which characterises most volcanic products, aided by pressure and time, is quite sufficient to bring almost all volcanic ejecta into the lithological condition of a compact conglomerate. The earlier explorers, especially those who, under the auspices of the British Government, at the commencement of this century, were charged with the unrolling of the papyrus MSS., formed, very unservedly, the conclusion from the state of these ancient sheets of vegetable matter, that they had all been exposed to a temperature sufficiently high to burn them into true charcoal, which seemed corroborated by the wood book-cases in which they were enclosed having been reduced to the like state. They thence concluded that it was liquid lava that had entered the city and had set it on fire—a conclusion which, independent of the indisputable fact that the material excavated through, at the theatre for example, is not lava, and never flowed as that does, is hard to be reconciled with the preservation with comparatively little injury of the wall pictures, and of several other objects extracted from the ruins, and in the museum at Naples. Sir Humphrey Davy, whose great chemical and physical knowledge, and rapid and accurate powers of observation entitle his opinion to

great weight, when at a later period he came to maturely consider and experiment upon possible methods of unrolling the papyri, came to the conclusion that they had never been exposed to a temperature even approaching ignition, and that their state so much resembling that of dense vegetable charcoal, was the result of 'eremacausis,' or slow oxidation due to time, air, and moisture, and that thus the material of these rolls, however resembling charcoal to the eye, was, in fact, more analogous to that of very dense peat. Against this view, however, it was found by Dr. Wollaston, I believe, that no volatile or empyreumatic matter was evolved on submitting a fragment of the MSS. to dry or destructive distillation, and it was observed that when presented to an ignited taper, the material burned with a slow creeping combustion, but without any flame, precisely as does well-burned dense charcoal. And upon these results opinion began to revert to Sir William Hamilton's notions. Large pieces of timber have been found in various parts of the excavations which have been made, and notably in the interior of the theatre, which were perfectly black, and presented to the eye all the appearance of charcoal throughout. I was, myself, enabled to extract from their matrices or sockets in the volcanic material, dug through above the seats of the theatre, some large pieces as much as four and a-half inches square, which had probably formed parts of the roof, which not only presented to the eye and to chemical examination all the characters of true charcoal, but also afforded one indication, which, I believe, is decisive in distinguishing that material from dense peat, or the result of eremacausis. If one piece of hard well-burned charcoal be rubbed against another, or indeed be rubbed by any hard body, a peculiar low gritting sound is emitted by the charcoal, which, when once attentively heard, can never be mistaken for any other sound. This sound was most distinctly emitted by the pieces of charcoal I have above referred to, and I cannot avoid the conclusion that the timber-work of the theatre, of which these formed a part, was actually set on fire and burned. Bringing into connexion with those facts those mentioned in the letter of Pliny the younger, that his uncle could not land in consequence of the hot material that fell upon his vessel, may not the fact have been that parts of Herculaneum were actually set on fire (as was Ottaviano at a much later period) by heavy flakes of material above the temperature of ignition, projected or rolled down over it, while other, and perhaps far larger, portions were merely encased in volcanic material and at a temperature not exceeding that of boiling water. Even that temperature would be sufficient greatly to increase the progress of slow combustion, or oxidation, which has caused the papyrus rolls so much to resemble true charcoal.

The facts which we have at command relative to the destruction of Herculaneum are, however, far too meagre and incomplete to warrant anyone in forming any definite theory of its conditions; and I by no means wish to present much more than negatives as tolerably certain with respect to it. The phenomena which appear to me

to rest upon a tolerably sure foundation with respect to Pompei and Stabiae, negative the possibility of Herculaneum having been overwhelmed by wind-carried dust, as does also the lithological character of the volcanic conglomerate with which it is actually covered.

The long historical experience which we possess of the eruptive phenomena of Vesuvius appear to militate conclusively against its having been entombed by *illuviones* of mud. The views of Sir Humphrey Davy are clearly against the notion that the covering material was in its general mass at a temperature even approaching that of ignition. On the other hand, we have a clear indication that the woodwork of the theatre, and probably of other buildings, was actually burned; and we have the statement, though at second-hand, of Pliny the younger, who was not an eye-witness, that hot and black pieces of burning rock, and other igneous materials, fell upon his uncle's ships in increasing quantity as he approached the shore, his landing upon which they hindered. With the better attested example of the conflagration of Ottaiano before us, we cannot deny the plausibility of the view that Herculaneum, after having been set on fire, probably in many places, by heavy igneous projectiles, either from the crater or from lateral *boccas*, such as those which opened on the flank of the mountain in 1858, was overwhelmed by coarse but discontinuous dry material at no very high temperature, which, as it rolled down, broke up smaller, and finally streamed in upon the city, and soon smothered out any fires that may have been established in its buildings.

XXVII.—ON THE AGE AND MODE OF FORMATION OF LOUGH NEAGH, IRELAND; WITH NOTES ON THE PHYSICAL GEOGRAPHY AND GEOLOGY OF THE SURROUNDING COUNTRY. By EDWARD T. HARDMAN, Assoc. R. C. S. I., F. C. S., &c., of the Geological Survey of Ireland.

[Read January 13, 1875].

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I. *Introduction.*

LOUGH NEAGH is a large body of fresh water, which forms a lake of considerable dimensions in the eastern part of the province of Ulster. It is situated between, and includes portions of, the counties Derry, Antrim, Down, Armagh, and Tyrone. Its greatest length is 19 miles, including a small lake at the north-west corner—Lough Beg, the Little Lake—about 4 miles long, and only $1\frac{1}{2}$ wide, now only connected by a narrow strait with the larger lake, which averages from 10 to 12 miles in breadth, and in shape is nearly a parallelogram. It is, therefore, very much larger than any other lake in the United Kingdom, its area being at least 150 square miles; and it can even bear comparison with some of the most important European lakes, in size at least, if not in picturesque appearance. It is rather shallow, however, the general depth varying from 20 to 50 feet, gradually increasing towards the northern shore, which becomes suddenly very steep, forming a “deep” reaching in one place to 102 feet.

The line of its greatest length lies in a direction about N. 15° W. and S. 15° E. Now, this agrees very fairly with that of the principal ice-flow, which has glaciated and marked the surface of other parts of Ireland; and although over the greater portion of the country surrounding the Lough, little or no striation has been observed, yet there is the evidence of transported blocks, as well as the general shape of

the drift-mounds, that here the ice took that course also;* so that the coincidence between the lines of ice-flow and the longest diameter of the Lake might naturally lead one to the inference that the Lake was originally formed by the action of the moving ice. But that this is not so, I hope to be able to prove in the following communication: for it can without difficulty be shown that it existed long before the great Glacial Epoch, and that its age can be approximately fixed between the end of the Miocene, and before the Post-Pliocene period.

II. *Sketch of the Geology and Physical Geography of the District.*

It will be necessary to glance at the general geology of the neighbourhood; but detailed accounts have been published by the following writers:—Sir R. Griffith, Bart.;† General Portlock;‡ Sir R. I. Murchison, Bart.;§ Dr. Berger and Rev. W. Conybeare;|| Professor Harkness;¶ Professor W. King;** Mr. John Kelly;†† Dr. Scouler.‡‡ It will, therefore, be only necessary to refer to the large divisions.

The Lough itself lies 48 feet above the sea level: in its immediate neighbourhood, and surrounding it on the east, west, and north sides, is the Miocene basalt. This stretches away in all these directions, rising as it goes, until it at length reaches some considerable altitudes. The chief of these, proceeding round from the east, by north, to west, are: Divis, 1567, Agnew's Hill, 1558, Slemish, 1457, Slieve-na-nee, 1782 feet; with others of minor elevation on the east. On the north

* The only reliable ice-striae observed by me in this district were—Rousky, near Stewartstown, on limestone, S. 10 E.; Brackagh, Slieve Gallion, metamorphic rock, N. and S.

† Geological and Mining Surveys of the Coal Districts of Tyrone and Antrim (1829); Notes Explanatory of the Subdivision of the Carboniferous System, "Dub. Geol. Soc. Jour.," vol. vii.; Notices on the Geology of Ireland, "22nd Rep. Brit. Assoc.;" Notice of an Additional Permian Locality in the County of Tyrone, "Dub. Geol. Soc. Jour.," vol. viii. † and many other works.

‡ Report on the Geology of Londonderry, and of parts of Tyrone and Fermanagh.

§ On the Recent Discovery of Fossil Fishes (*Palæoniscus Catopterus*) in the New Red Sandstone of Tyrone, "Proceed. Geol. Soc. Lond.," vol. ii. (1835); also, The Permian System, as applied to Germany, &c., "13th Rep. Brit. Assoc."

|| On the Geological Features of the North-Eastern Counties of Ireland: "Trans. Geol. Soc. Lond.," 1st series, vol. i.

¶ On the Hornblende Greenstones, and their Relation to the Metamorphic and Silurian Rocks of the County Tyrone, "33rd Rep. Brit. Assoc."

** On the Occurrence of Permian Magnesian Limestone at Tullyconnel, near Artree: "Dub. Geol. Soc. Jour.," vol. vii.

†† On the Subdivision of the Carboniferous Formation of Ireland: "Dub. Geol. Soc. Jour.," vol. vii.

‡‡ Observations on the Lignites and Silicified Woods of Lough Neagh: "Dub. Geol. Soc. Jour.," vol. i.

the ground is comparatively low, forming a narrow depression along the course of the Lower Bann to the sea, the highest point being about 700 feet, some distance south of Ballymoney. On the north-west and west, the basaltic ground rises again to the following heights:—Benyevenagh, 1260; Keady, 1101; Donald's Hill, 1378; Benbradagh, 1531; Carntogher, 1527; Corick, 1527; and Craig-na-shoke, 1996 (both on a large outlier to west); and, finally, Slieve Gallion Carn, 1625, another outlier, south-east of the last.

On the southern shore of the Lake, overlying the basalt (which there is very low), and extending for some miles inland, is a thick and extensive deposit of plastic clays and sands, which I shall refer to more particularly presently.

All around the basalt, on the side most remote from the Lough, the Mesozoic or Palæozoic strata crop out; and the denudation of the softer of these rocks has given rise to a more or less well-marked escarpment of chalk or basalt. On the west side a very distinct escarpment of chalk extends from near Magherafelt southwards to the south-east of Stewartstown, where it, as well as the basalt, disappears under the clays above mentioned. Beneath the chalk, and stretching westward, are greensand, new red sandstone (Keuper and Bunter), Permian (a small patch), coal-measures (two small patches), preserved by a series of large faults—of which more anon—carboniferous limestone, and sandstone, and so-called old red sandstone, the true horizon of some of which is, I believe, not yet fully made out.* These all extend in an irregular sweep from Draperstown, on the north, to Armagh; while south-east of Draperstown, and some miles west of the chalk escarpment, is a large mass of granite, with metamorphic rocks, schists, &c., probably of Silurian age, forming a long ridge called Slieve Gallion, on top of which is an outlier composed of basalt overlying chalk, and this superimposed on new red sandstone. A similar outlier of chalk and basalt is found N.N.W. of Draperstown—Craig-na-shoke. These outliers occur at heights of 1625 and 1996 feet, respectively, over thin chalk.

Crossing now to the east and south-east side of the Lough, a very similar disposition of strata is seen. The basalt and chalk emerging from under the clay beds not far from Portadown show an escarpment running round by Lurgan, Moira, White Mountain, Δ 820; Collin Glen, Black Mountain, Δ 1272, some three miles west of Belfast, and so on towards Carrickfergus.

Retracing our steps southwards, we find the new red beds—capped in one or two places by a thin layer of the Rhætic beds—cropping out from under the escarpment; but not until we come round to the north of Armagh do they rest on anything higher than Silurian rocks. These form high ground to the south-east; and in

* It is most probable that some of this will be found eventually to belong to the carboniferous sandstone.

the opinion of Professor Hull, F. R. S., and the late Messrs. W. B. Leonard and J. L. Warren, this high ground is, partly at least, due to upheaval since the deposition of the Mesozoic strata.*

Continuing round by Armagh, Benburb, Ballygawley and Pomeroy, we find the underlying carboniferous, together with the old red sandstone (?) and Silurian rocks again, and finally end with the continuation of the metamorphic rocks of Slieve Gallion.

In this circuit all the ground rises more or less rapidly, as the distance from Lough Neagh increases, with a remarkable exception—which is, that immediately south of the Lake is found a line of low ground similar to that extending along the Lower Bann, and seeming to be the prolongation of that, taking much the same direction; the level being all under 250 feet. The line runs from the Upper Bann foot to Newry, and Carlingford Bay; forming, from Portadown nearly, a great flat, along which the Newry Navigation Canal is brought.†

The country, therefore, resembles a rude trough, widening out towards the centre, or imperfect basin, as is shown in the accompanying diagrammatic section, taken from Slieve Gallion on the N. W., to Belfast Lough on the S. E. (Plate XII., fig. 1).

The district is drained by seven principal rivers, with their tributaries. The most important are these:—The Upper Bann, Blackwater, Ballinderry River, Moyola, and Mainwater, all flowing *into* the Lough. The outgoing river is the Lower Bann, which flows from the north-west corner through Lough Beg, falling into the sea a little below Coleraine.

Of the former, the most ancient appear to be the Upper Bann, and the Blackwater, entering the Lough within a few miles of each other, and draining the country to the south, south-east, and south-west. A very thick deposit of clays extends across a wide area around the mouths of these rivers, in such a manner as to lead to the conclusion that we have there the ancient delta of one or both of them; or at least of a river which formerly found its way into the Lough at some point along the southern shore. For there is nothing like this great clay deposit to be seen in a similar position with regard to the other rivers excepting a small delta at the mouth of the Moyola, of trifling extent and thickness, and which is undoubtedly of much more recent date, for it seems to be above the drift, whereas the former lies underneath this. It has silted up the part which divides Lough Neagh from Lough Beg; but, although the Moyola is now

* Ex Mem. Sheet 36: "Geol. Sur. Ireland," p. 11.

† I, at one time, thought that this north and south valley of depression might have some connexion with a large fault running in the same direction in the neighbourhood of Newry. But this, I am informed by Professor Hull, is of much earlier date than the Miocene period, and there is certainly no trace of it to be seen near the Lake.

an important working stream, committing a good deal of havoc among the rocks of a large district, its delta covers an area of, at most, 12 square miles, while that around the mouths of the Bann and Blackwater cannot occupy a surface of much less than 180 square miles; so that if the whole Lake were now drained, there would be exposed a Tertiary formation, of no mean dimensions, in this part of Ireland. I now propose to describe these clay beds.

III. *Description of the Lough Neagh Clay Beds and Lignites, and their Stratigraphical Position.*

The country around Lough Neagh is thickly covered with drift—often to a depth of more than 50 feet—consisting of boulder clay, sand, and gravel. Underneath this, on the northern half, comes the well-known basalt; but on the south, newer beds of lacustrine origin are seen. These beds are very thick, are continuous round the southern margin, and extend inland for a distance of from four to five miles, but die away near the centre points at both sides of the Lough, viz., at the mouth of the Ballinderry River, county Derry, on the west; and near Sandy Bay, county Antrim, on the east. They are composed of various stratified and laminated clays—white, grey, and bluish or purplish (generally slightly sandy, but often fine enough to be used in the manufacture of coarse pottery)—together with beds of sand, “ironsand” (?), concretionary hard grey sandstones, iron pyrites—sometimes in considerable quantities—occasional beds of lignite, and hard siliceous clay-ironstone nodules. In these last, and in the sandstones, reed-like plants of a rather recent aspect, in some cases retaining the woody tissue; and in the clays numerous fragments of black wood, apparently oak and pine, are obtained;* but up to this no trace of a fauna has been discovered.† The order in which the different beds of clay, &c., alternate has never been accurately ascertained; for no continuous section is to be seen, and in few instances has a greater depth than 20 or 25 feet been pierced through—with two exceptions, to be mentioned presently. It has so happened that in each of the places where the clay has been raised for pottery manufacture, a constant quality has been got for the above thickness, although in pits a few fields away it is found of a different colour and appearance. The beds lie nearly

* By Mr. W. H. Bailly and myself. Near some clay-pits at Sandy Bay similar nodules, containing leaves of dicotyledonous plants were also found by Mr. M. Henry; but it is difficult to say if they came from these clays. Mr. Bailly informs me they appear to belong to the following genera:—*Sequoia Couttsiae* (?), *Alnus*, *Quercus*, *Fagus*, *Salix*.

† Since this paper was sent in for publication shells have been obtained from one locality. (See Appendix.)

horizontally, with a very slight dip towards the Lake, the angle not exceeding at the most 1 in 20, or 3° ; rarely more than 2° .

If we were to attempt to calculate the thickness of these deposits, from the amount of dip and their extent in the line of it, I fear we should be led to over-estimate it, as even the small dip of 2° would give a thickness of 1200 feet at the southern shore of the Lough. This seems to be excessive, when it is seen that the northern part of the Lough is but 100 feet deep at most, where these clays have not extended; but I think, considering the large area they occupy, and the former southern expansion of the Lake, they cannot be under 500 feet thick in some places.

In only two localities have they been pierced to any considerable depth. These are referred to by Sir Richard Griffith.* In one of them, in the townland of Annaghmore, close to the hamlet of that name in the parish of Clonoe, two miles S. E. of Coalisland, borings were made for 294 feet, which were said to have gone through nothing but these clays, the underlying new red sandstone not being reached. This is likely, as the bright red shales and clays of that formation are well known to the miners of the neighbourhood, under the name of "red shivers,"† and could hardly be confounded with these grey and blue beds; but at least 30 feet of drift must be allowed for, which reduces the depth to 264 feet. This seems probable, for, taking the dip at 2° , the thickness here would be theoretically 250 feet.

Another boring was made on the Lough shore at Sandy Bay, county Antrim, the details being as follows:‡—

SECTION I.—*Boring at Sandy Bay.*

	Feet.	Inches.
Blue clay,	10	0
Black lignite mixed with clay,	25	0
Clay,	2	6
Black lignite,	20	5
Clay,	4	0
Black lignite,	15	0
	<hr/>	<hr/>
	76	6

The thickness of the lignite beds here is remarkable. Could it be possible that the borers inadvertently substituted the clay for the lignite, and *vice versa*, in their Journal? In the vicinity of this trial

* "Second Report of Railway Commissioners," p. 22; also Portlock's "Report," &c., p. 167. These borings were made in search of coal.

† Probably from the German *Schiefer*.

‡ *Loc. cit.*

one bed of lignite was observed by me. It occurs under a bank of thin boulder clay.

SECTION II.—*Section seen at Sandy Bay.*

	Feet.	Inches.
Boulder clay,	6	0
Black imperfect lignite,	1	0
Grey plastic clay just seen.		

7 0

Several old clay pits are to be seen about here in which lignite has been obtained. They are shallow, and the lignite has rarely exceeded a foot thick. It has occasionally been used as fuel. My informant, an old man living close by, said that the "black wood" and grey clay had also been got at Sandy Bay Point, about half a mile to the south, but never thick. I think, therefore, that the above section of Sir Richard Griffith's must be incorrect in details; but it is valuable, as showing the thickness of the whole deposit at this place.

It is indeed unfortunate that the drift prevents a perfect understanding of the thickness and nature of these beds. All the data there are to go on, being for the greater part derived from the pits which have been sunk from time to time in search of the kind of clay that is adapted for the local pottery manufacture, must necessarily be somewhat imperfect. At the same time it has been quite possible to arrive at an approximate determination of their extent in area, and a true one of their order of superposition in relation to the other formations which are met with in the district.

I shall, therefore, mention some of the more important localities and sections which have come under my own observation, while engaged on the work of the Geological Survey, the country included comprising the greater part of that lying under this formation; the exception being a small portion to the south-east, surveyed by my colleague, Mr. F. W. Egan.*

Commencing on the north-west, on the opposite side to Sandy Bay, at the mouth of the Ballinderry River, townland of Mullan, the following is reported by Portlock:†—

SECTION III.—*On Ballinderry River.*

	Feet.	Inches.
3. Alternate layers of sand and imperfect lignite, in fragments, 1" to 4" thick,	6	0
2. Bluish stiff clay, }	Thickness not given.	
1. Finely crystalline basalt, }		

* See Ex. Mem., Sheet 47, "Geol. Sur. Ir.," p. 49.

† "Geological Report," &c., p. 161.

This is an important section, as showing the relation of the *basalt* and clays to one another.

Three miles south of this, at Lurgyroe, near Kiltagh Point, white clay was formerly raised. Still proceeding southward, a great expanse of bog and drift is crossed, and no clays are seen until we reach the neighbourhood of Mountjoy Castle. A short distance under this, on the edge of the Lough, are some pits in white clay, which was found to be of excellent quality for pottery, and was worked for a while but the undertaking was afterwards abandoned.

The section as given by the tenant of the ground is—

SECTION IV.—*Townland of Magheralamfield.*

	Feet.	Inches.
Drift, gravel,	2	0
Fine white, tough, soft, potter's clay, at least,	15	0
	<hr/> 17	<hr/> 0

The top of the clay was visible.

West of this point, about a mile and a-half, on the Duckingstool River, forming the boundary between the townlands of Aughrimderg and Gortnaclogh, and close to what was Bellville Wood, three small trial pits were put down, in the belief that the light grey clays were coal-measure shales. They were sunk about 11 feet through light bluish-grey clays, fine, tough, and laminated, containing irregular beds of iron-pyrites, sometimes in lumps weighing half a pound, together with pieces of coaly-looking matter (wood), and fragments of plants, all of which were to be seen in the spoil. No hard rock was met with.

About 350 feet west of these, in a drain, hard fine-grained crystalline amygdaloidal dolerite is found. And, although the actual junction is not seen, I think that, from the appearance of the ground, forming as it does a very gentle slope between the two, and with nothing like an escarpment—which would probably be to some extent visible were the hard rock uppermost—the conclusion is correct that the basalt underlies the clay formation.

The clays here occur at a height of about 80 feet above the present level of the Lough, and 130 above sea level.

Tracing the boundary towards Coalisland, we come to the Black Bridge, near which, in Dernagh, parish of Clonoe, a trial was made for coal in the following strata:—

*SECTION V.—*Townland of Dernagh.*

	Feet.	Inches.
Surface-soil, &c.,	1	0
Brick clay, . . } Drift	3	0
Gravel and sand, }	15	0
Blue, red, and variously-coloured plastic clays, none white, containing occa- sional layers of black flint(?), 2" thick, ending in a rotten dark stuff "like manure" (probably lignite): in all, .	173	0
	<hr/> 192	<hr/> 0

The layers of black flint mentioned by my informant are, I suspect, in reality, only nodules of clay-ironstone, which often occur in these clays. The description given of them did not correspond at all with that of silicified wood, with the appearance of which moreover the man was quite familiar. No "red shiver," or triassic rock, was found; but I am inclined to think that some of the uppermost beds here must belong to the drift. However, even allowing a margin of say 20 feet for this, the section shows a remarkable thickness still, especially as the spot cannot be far from the boundary of the deposit.

Passing over some pits and borings where the clays have been proved, in the immediate neighbourhood of Coalisland, and $3\frac{1}{4}$ mile, from the nearest edge of the Lough, we come to where they have been rather extensively worked for pottery manufacture; viz., in the townlands of Creenagh, Annaghmore, Ballynakilly, and Drumenagh. Here they are best seen, therefore; yet the information to be obtained is rather meagre, because no continuous section is to be found, and the workmen rarely sink deeper in them than from 10 to 12 feet in any one place.

Near the eastern corner of Creenagh, close to the Torrent River, is a pit in dark purplish and brownish grey laminated plastic clay, sometimes micaceous, full of fragments of black wood (? oak and a coniferous wood). The section is—

SECTION VI.—*In Creenagh.*

	Feet.
Coarse gravel (drift),	6
Dark plastic clay, with wood,	12 seen.
	<hr/> 18

* Obtained from the sinker, Mr. James Killen.

A little further east, the light grey and white variety is found, sometimes coming to the surface. It is first seen 600 feet from the above pits, and is visible at intervals for 600 more, at which point a pit went through 12 feet of it under 14 feet of drift. It doubtless comes above the darker clay, as there is a slight dip about 2° to the east, and the sections here must be somewhat as below :—

SECTION VII.—*Probable relation of clay beds, Creenagh.*

	Feet.
4. Drift, boulder clay, on top gravel, . . .	14
3. Light grey and white potter's clay, sometimes sandy and micaceous, with fragment of wood and plants, and clay-ironstone, about, . . .	20
*2. Thick, hard, grey, concretionary sandstone, . . .	1
1. Dark laminated clay; wood abundant, . .	15
	—
	50
	—

Half a mile further south, on the strike of the above white clay pit, same townland, is a pit giving the following section :†—

SECTION VIII.—*In Creenagh.*

	Feet.
3. Drift, { Gravel,	12
{ Boulder clay,	10
2. White potter's clay, somewhat sandy and micaceous, with large hard clay-ironstones, altered and coated with brown hematite—and concretionary sandstones,	16
1. Hard, grey, concretionary sandstone, irregular layer,	1
	—
	39
	—

Tracing the beds further south, the next section of any importance occurs at Drumenagh, half a mile north-east of Killyman church, and nearly five miles from the margin of Lough Neagh, at the nearest point.

* This bed is found further south, on the strike, and may extend to here. (See below.)

† I am indebted to Mr. Robert Byrne, owner of the Ballynakilly Pottery Works, for much information about the clays of this locality, cheerfully afforded.

SECTION IX.—*At Drummenagh Pottery.**

	Feet.	Inches.
6. Soil, sand, and drift clay,	12	0
5. Blackish clay (?), boulder clay,	2	0
4. Light grey, tough, somewhat sandy, plastic clay, with iron pyrites, and hard siliceous clay-ironstone nodules, altered to hematite on exterior, con- taining reed-like plants,	20	0
3. Hard concretionary sandstone nodules, with plants—very troublesome to work- men—forming an irregular bed, about	0	4
2. Light grey clay, occasional ironstone, with plant remains,	10	0
1. Irregular bed of lignite, or black wood, very sulphureous, has been burned as fuel, about	0	6
	<hr/> 44	<hr/> 10

Bed 1 has not been positively identified as *lignite*. Some of the men describe it as being merely lumps of black wood scattered through the clay. However, it has already been mentioned (p. 176) that the same description was given of the undoubted lignite of Sandy Bay.

The following pebbles occurred here in the white clay. They were in some parts abundant; all were rounded, but small:—†Basalt†††, chalk flints†, quartzite†, red granite††, hornblendic gneiss;† also iron pyrites in curious concretions, and in bunches of small crystals. Similar pebbles were found in all the other pits examined by me, but not always abundant. But it is to be remarked that in no instance has any specimen of the celebrated silicified wood of Lough Neagh been found in them, although a good opportunity for its discovery has thus been afforded over an extensive area.

The following section is extracted from the "Journal of the Royal Geological Society of Ireland,"† as it proves the clays at their greatest distance from the shores of Lough Neagh—six miles. The section was procured when sinking a well in Roxborough Demesne, close to the

* Some of the clays are seen in the bed of a small stream flowing past the north end of the clay-yard.

† The number of crosses signifies the respective abundance of each.

‡ On some Timber Found at a Considerable Depth from the Surface in the County of Tyrone. By William Murray, Esq., M. R. I. A. "Jour. Roy. Geol. Soc. Ir.," part iii., pt. 1, p. 75.

River Blackwater ; a large tree of black wood (coniferous), impregnated with iron pyrites, being found at a depth of 57½ feet.

SECTION X.—*At Roxborough Demesne.*

	Feet.	Inches.
Strong sandy loam, } Drift (?)	16	0
Strong red clay, }	16	0
White pipe, or potter's clay,	12	0
Light-coloured fine sand,	4	0
Yellow clay,	9	6
<hr/>		
Fossil tree, supposed <i>in situ</i> , at	57	6
Yellow clay,	18	0
Gravel, with a strong spring of water,		
<hr/>		
	75	6
<hr/>		

The author considers "the tree, &c., appears to be only a part of the similar deposits of lignite in that district."

The above are the only sections penetrating any depth in the clays that have been obtainable; but in very numerous places they have been proved in well sinkings, and other artificial openings, records of which I have obtained, both close to the Lough, and for a distance inland, showing them to form a continuous deposit all around its southern margin, from Ballinderry River on the west to Sandy Bay on the east. But as these do not further add to our knowledge of the formation, it would but prove tedious to mention them in detail: suffice it to say, that the white clay appeared to be the most abundant; lignite was but seldom met with, and then in thin irregular beds;* and silicified wood (so-called) was only obtained once in these clays, and under circumstances that I do not think prove it to have been *in situ*; nor, in fact, do the specimens recorded appear to be the true silicified wood at all.

Silicified Wood.—These specimens were got near Sandy Bay, at Ahaness, by Barton,† forming part of "a stratum of black wood, four in thickness, which reposes on another stratum of clay." It is "of one uniform mass," and "capable of being cut with a spade." Sometimes the wood will not easily break; in that case it requires the aid of some other tool to separate it from the mass; and may, "if properly

* Some shallow pits were formerly sunk at Washing Bay, north of Maghery, on some thin beds of lignite, but they were soon abandoned, the fuel not being of good quality.

† Lectures on the Natural History of Lough Neagh (1757), quoted by Dr. Scouler, *Observations on the Lignites and Silicified Woods of Lough Neagh*; and after him by Portlock, "Geol. Report," p. 75.

done, afford a block of two, three, or four hundred pounds, which, being carefully examined, is found to consist more or less* of stone."

The true wood, or what is generally known as the silicified wood of Lough Neagh, is usually nearly or entirely white, although some specimens are of a dark brownish colour, the greatest amount of organic matter found in it being not more than 20 per cent. ;† and, according to Bischof, but 1 per cent. It is perfectly hard, and it would be a matter of some difficulty, I fancy, to cut it with a spade; nor do I believe it is merely the silicified lignite bleached white in the drift by atmospheric influence.‡ Moreover, we are only told that the above specimens consisted "more or less of stone," which is a very vague statement, considering the period at which it was penned, and would just as well be applied to pyritous wood, which is known also to occur in the clays (see p. 181), as silicified. I think, therefore, that on the whole the evidence is against the classification of these woods as a member of the clay and lignite formation. Nor should they be localised as Lough Neagh woods at all, having really no more to do with it than the accompanying pebbles of Derry and Donegal rocks occurring in the boulder clay of the same district.

One point against their co-extension with the lake lignites is the important fact, that they are found in the drift from six to nine miles *north of the northern limit of the clay beds*. Dr. Scouler says that "the district in which the fossil wood is found extends from beyond Cranfield on the north, to the parish of Segoe in Armagh on the south;"§ and Dr. Macloskie states specimens have been found "northwards beyond Randalstown."||

Now, even supposing the clay beds to have formerly continued northwards to those localities—an extremely improbable circumstance—it would be hardly possible for the fossil woods to occur in the glacial drift there now, seeing that these, as well as such vestiges of the clays as had escaped previous denudation, must have been carried southwards by the flow of ice. It is clear, therefore, that these specimens must have been brought from some more northerly situation, and it is most likely that they, in common with those found in drift to the south, had their original *locus* in the basalt¶ itself; no doubt forming parts of the beds of lignite associated therewith, and certainly much more liable to silicification, by the perco-

* Especially *less*, it would appear from the above.

† Dr. Hodges quoted, but from what publication not specified, by Rev. George Macloskie, M. A., LL. D., On the Silicified Wood of Lough Neagh, "Jour. Roy. Geol. Soc. Ir." (N. S.), vol. iii., pt. 3, p. 163.

‡ *Loc. cit.*

§ *Op. cit.*, p. 238.

|| *Op. cit.*, p. 164. It is to be regretted, however, that the writer does not give his authorities for this and other statements, which it would seem relate to facts that have not come under his own observation.

¶ The authors of the above papers both incline to this view.

lation of water through the porous and easily decomposable basalt, than when imbedded in a nearly impervious bed of clay.*

From what has now been said, the order of superposition of the basalt, clays, and drift will doubtless be considered sufficiently made out; but it may be well to recapitulate the evidence on this head.

(1). In at least one instance, a clay in every way similar in character to that observed at so many other localities has been found actually resting on the basalt.†

(2). That where the basalt and clays have been found adjacent to each other, the form of the ground is such as to make it most unlikely that the basalt could be uppermost.

(3). That pebbles of basalt frequently occur imbedded in the clays. (This has also been noticed at Glenavy by Dr. Scouler.)

(4). The negative evidence, that, while numerous junctions of the chalk and basalt are visible over a very considerable area, no trace of such clays has ever been observed between them.

(5). Lastly, the plant remains associated with them are of too recent an aspect to permit of the supposition that the clays could belong to a period antecedent to the chalk. The only place then left for them is that between the basalt and the drift.

It might, perhaps, be thought unnecessary to enter so fully upon this part of the matter, as these clays have been already relegated by previous writers to the "Tertiary"‡ system, or "Miocene"§ age. But, so far as I can learn, this has been partly by guess-work, and partly by reason of their similarity to the Bovey Tracey deposit of Devonshire.¶ No evidence has been given to back up these surmises. Much doubt seems to have existed in the minds of some of the writers

* Garrulous old Isaak Walton does not neglect Lough Neagh in his long-winded account of the miraculous properties of certain waters. He says, quoting Camden, that "Lockmere in Ireland" in a few hours turns a rod or wand to stone. In a corrective note on this, Professor James Rennie, M. A., Professor of Zoology, King's Coll., Lond., one of his editors, and who has evidently but a poor opinion of Isaak's Natural History, says, "he means Lough Neagh, which certainly petrifies wood, but not in a few hours" (!)—The "Complete Angler:" ed. 1833, p. 56. The first edition was published 1653, and it is interesting to find the reputation of the Lough celebrated before that time, and that the silicified wood was known at that early period. The same idea as to the silicifying or petrifying qualities of the waters of Lough Neagh is even at the present day very widely spread, and is a very good illustration of how myths arise from the misapplication of facts. It is stated as fact in Sullivan's "Physical Geography"—a book much used in schools. Analyses of the water have been made by Bischof, and also by Professor Hodges, with a view to determining the question. As might have been expected, however, these analyses prove that the waters could possess no such quality, being really rather exceptionally deficient in mineral matter.

† See Appendix for another.

‡ Portlock's "Report on Londonderry," &c., p. 165; Griffith, "Report to accompany Geological Map," 1838; *ibid.* "Report of Brit. Assoc.," 1852, p. 48.

§ Prof. W. King, "Synoptical Table of Aqueous Rock Groups."

¶ Griffith, *loc. cit.*

in question, and several geologists appear to have differed very seriously as to their true position. Portlock considers the "upper beds" as probably of later date than the nucula clays of Derry,* which are now known to belong to the drift. Griffith's† classification of them with the Bovey Tracey beds does not at all define their place in connexion with the basalt, although it is true in a section given with his map they are placed above it; while Jukes, in his map of Ireland, colours them as pleistocene; and my friend, Mr. G. H. Kinahan, suggests that they are a Pre-Glacial drift.‡ It thus becomes of importance to assign them a definite position relative both to the basalt and the drift, and to point out the reasons for doing so.

I now propose to class these beds as *Pliocene* on the following grounds:—

After the close of the basaltic outflow the whole country was, as I shall presently show, subjected to most violent effects of upheaval, or depression. The entire district became dislocated, and cut up in every direction by large faults, some of considerable magnitude. At the same time extensive denudation took place, removing in some parts as much as 1000 to 2000 feet of solid strata. This was followed by the deposition of the Lough Neagh clays. We have here, therefore, unconformability, accompanied by evidence of an immense lapse of time, which alone would, I think, justify us in putting the clays and the basalt in different systems. Added to this, the plant remains have an exceedingly recent aspect, and lignite is often not far removed from peat. On the whole, indeed, the beds bear some resemblance to the older Pliocene of the Val d'Arno, Florence, as described by Lyell (Student's Elements of Geology, p. 184); and I am glad to be able to say, that both Professor Ramsay and Professor Hull consider the evidence as in favour of Pliocene, and approve of that classification.

The delta of the Moyola has been alluded to. This has silted up the space between Loughs Neagh and Beg, forming a large flat called the Creagh; and there is good reason to believe that at least the top beds of this—which are indeed the only ones that have been observed—are Post-Glacial. These consist of a few beds of blue clay and sand: the former containing erect stumps of oak, just as they occur in recent bog. They are now covered by thin bog.

The following is, therefore, the order of superposition of the formation around the Lough:—

* Portlock's "Report," &c., p. 165.

† "Report of British Association," 1852, p. 48.

‡ On Glacialoid Drift: "Geological Magazine," decade II., vol. i., p. 173.

Recent, . . .	{	Fresh-water shingle on west and southern shores of Lough.
	{	Alluvium.
	{	Bog.
Post-Glacial, .	{	Moyola clays and sand, with erect tree-stumps.
Drift deposits, .	{	Upper boulder clay(?), middle gravels, lower boulder clay.
Pliocene, . . .	{	Lough Neagh pottery clays, sand, lignite, and clay-ironstone.
Lower Miocene(?),	{	Basalt, with hard lignite (and sili-cified wood?).
Eocene, . . .	{	Trachytic rocks of Tardree, &c.
Cretaceous, . . .	{	Upper chalk, with flints.

Former Level of the Lough.—This must have been at least equal to the highest point where these Pliocene beds are now found—that is, certainly 120 feet above the sea, where they have but a thin skin of drift over them. But at some points within their boundary, making a generous allowance for drift, these beds must lie at a height of 140 feet; the former number is, however, undoubtedly within the mark. As the level is now 48 feet only above sea level, it follows that the Lake must have been at one time 72 feet deeper than at present, or at least 175 feet at the deepest part. And if the land surrounding it be contoured with a 120-foot line, its dimensions become very respectable indeed, being nearly twice its present size. But, in fact, this must be underrating it, both in depth and surface; for the clays must have been largely denuded since their deposition. Of the amount so removed there is, of course, no means of judging; but it is possible that a great part of it was swept away during the advance of the Post-Pliocene ice-sheet across these very soft strata. There is a greater difficulty, however, as to the northern extent of the water, because we have no way of ascertaining positively how far the existing contours of that ground differ from those which it had when the level was as high as is shown by the southern boundary of the clays. But the northern shore may be supposed to have been higher, because denudation is certain to have occurred by one means or other. The former northern shore would, therefore, be close to the present one, as the 120-foot line is not far inland at present; and the great expansion of the Lake must have been southwards towards Armagh, while the great spread of the mud beds northwards shows that the whole Lake was in imminent danger of being silted up.

It is worth while to point out that the greatest general depth of the Lake is found near the north shore, which becomes very steep, reaching to 30 feet quite close to it, and to 102 within a mile; while the slope from the south end is very gradual, only 50 feet being gained in a distance of eight miles. The sudden deepening at the north nearly coincides with the direction and throw of two large faults detected

near Coagh, which form a deep trough in the strata, although, of course, not apparent on the surface now.

IV. *Time and Mode of Formation of Lough Neagh.*

It will be apparent now, that the existence of the clay beds furnishes us with some approximative chronological data as to the formation of the Lough; for it is clear that it must have been scooped out after the consolidation of the basalt, and prior to the great age of ice, which is called emphatically the Glacial period. The basalt is known to be of Lower Miocene age; the clays must, therefore, be intermediate between that and the Post-Pliocene; hence it is unlikely that ice could have anything to do with the digging out of the Lake basin. It is true that a trace of glacial action (so far as the transportation of large blocks) has been observed in the Miocene rocks of the Hill of Superga, near Turin;* but this may be best, perhaps, attributed to a wandering iceberg, just as in the present day blocks may have dropped in the Atlantic, far from the influence of ice, and could hardly denote a general glacial era. And it must be remembered that we are not now dealing with a case which could have been created by a mere temporary glaciation, but one which has required a very great amount of denudation to produce it; for there can be no difficulty in proving that whatever physical agents gave rise to the present appearance of the whole surrounding country† also caused the Lake, and *vice versa*, and this necessitated the removal of thousands of feet of rock over, at least, hundreds of square miles. An ice-sheet that would do this must have been of formidable dimensions, and would doubtless have left notable traces behind it—perhaps even an ancient boulder clay—but there are none. It would be unwise, therefore, to ascribe the birth of our Lake to a state of things that was admittedly of uncertain, and, at any rate, of very circumscribed existence.

A well-known writer on the ice question refers to the Lough Neagh district as a proof of the power of ice.‡ He considers that the superficial appearances are sufficient to show that it merely forms a part of one or more huge ice-striae, engraven during the last Glacial period, and denuded in part by the only other agent he has much faith in—the sea. But when we leave surface indications, and study the geology of the country, we find that it was shaped anterior to the Ice Age, and chiefly by atmospheric denudation.

* Lyell's "Principles of Geol.," 10th ed., vol. i., pp. 206–7. Mr. Moore in "Pre-Glacial Man;" also in "Jour. Roy. Geol. Soc. Ir.," vol. i. (N.S.), gives a diagram, constructed from Mr. Croll's calculations of the excentricity of the earth's orbit; one point of which he suggests may correspond with the supposed Miocene ice-reign.

† With very slight after modifications.

‡ Mr. J. F. Campbell, F.G.S., On the Glaciation of Ireland: "Quart. Jour. Geol. Soc. Lond.," May, 1873.

The Lake existed before the Glacial period: the Lake is still there (hardly even altered in shape); proving incontestably, to my mind, that the amount of ice-work has been insignificant indeed.

It must be clearly understood, however, that I have no intention of taking exception to the celebrated theory of the Glacial origin of many lakes, as to which there can be no question whatever; but it thus becomes a matter of greater interest to find a well-proven exceptional instance, like the present. And what adds to the importance of this case is, that it presents the phenomenon which Professor Ramsay had shown to be one of the "rarest things in nature," namely, a lake the strata surrounding which all dip inwards, so as to form a kind of bowl.

In his excellent paper on the Glaciation of the southern part of the Lake district, Mr. J. Clifton Ward, F. G. S., says: * "I do not think any case can be pointed to, in which a lake hollow has been directly formed at a certain spot, because of the presence of particular geological features at that spot." Such cases must be rare, and at any rate most difficult to prove. But, as will be seen further on, Lough Neagh can be shown to be one of these unusual instances; and from the remarkable geological structure of the district, there are exceptional facilities for the proof thereof.

Rejecting then ice as the originator of the Lake basin, let us turn to water (and atmospheric influences generally). With regard to this denuding agent, there is one satisfactory matter, and that is, we have not to search for doubtful traces in isolated localities, because we know that it has been ever present; and not intermittently, but through all time constantly at work. Yet it will not undertake a task such as the production of a great water-basin, unless certain conditions are favourable; and the most important of these is the determination by the natural features of a country as to the direction in which it shall run; and the circumstances must be such as to ensure the final carrying away of the materials abstracted during its flow over a given area. There would be little chance of a hollow being denuded in a great table-land of basalt, when all around it there must have been soft strata, easily broken up, such as the new red sandstone, and coal-measures, with others so susceptible of chemical influence as the chalk and carboniferous limestone. However, nature herself supplied the necessary condition, and by means of a series of great faults, the first rude form was given to the ground, which, having its corners and asperities afterwards removed by the powerful influences of "rain and rivers," frost, and "weathering" in general, resulted in a capacious reservoir, receiving the drainage of a very large area.

My theory of the formation of this Lough is shortly this:—After the basaltic flow had entirely ceased, no doubt after a considerable lapse of time, subsidences over a large area took place. These de-

* "Quar. Jour. Geol. Soc.," May, 1875, p. 163.

pressions corresponded with certain lines of parallel and transverse faults of large dimensions, which can be proved to extend across the ground comprising the plain and bed of Lough Neagh; and at the time of their occurrence must have given to the face of the country a rudely depressed shape, consisting of a series of steps to the north, north-west, and south, thus determining the chief flow of water into the hollow centre, so as gradually to carve out something like the features that this part of Ireland now presents to us. The egress of the water was provided towards the east, along what is now the valley of the Lagan, which there can be little doubt had its birth about the same period as Lough Neagh. Eventually, a greater amount of depression at the centre of the faults crossing the Lough gave a lateral upheaval on the east as well as the west, giving the finishing touch to the basin depression, and causing an inflow from all sides. The outflow may possibly have now commenced to take its way along the great valley of depression which it at present occupies. In the course of time, large rivers draining the high ground to the southward carried down immense quantities of *detritus* into the water-filled hollow, and spread it into a great delta: silting up indeed a large portion of the Lake. It is possible that some depression of the country to the north now ensued, draining the Lake to some extent; for, near Belfast, a clay deposit has been found containing *nucula oblonga*, &c.,* which is referred to newer Pliocene age.† It is unnecessary to trace the history of the Lough past this point, because from that time until the present day I believe the physical geography of the district has remained essentially the same.‡

It may be objected that the form of the country around Lough Neagh might with as much reason be ascribed to Pre-Miocene movements, for that it is nothing more than the great basin of the chalk and other secondary formations, covered by a skin of basalt, the flow of which adapted itself to the previous contour of the ground; but I think there is more than one argument to be adduced to the contrary.

1. In the case of a great outpouring of molten basalt over a large basin-shaped receiver, the ultimate surface would be more or less flat, no matter what the extent of the flow, or thickness of the deposit. This would subsequently have to be denuded away at the centre or thickest part; and, unless there were some particular conditions to

* Mr. J. McAdam, "Report Brit. Assoc.," 1852, p. 53; also Portlock's "Report on Londonderry," &c., p. 738 (Appendix).

† Ex Memoir, "Sheet 36, Mems. Geol. Survey of Ireland."

‡ No doubt the face of the country has been slightly modified by the action of ice during the Glacial period, and it is possible that our Lake was then partly remodelled; but the alteration must have been very insignificant, seeing that the new Lough bears the same general relation to the surrounding hills, &c., that the old one did.

determine the denuding agents to this point, there would be a vast majority of chances against such a coincidence as a recurring basin. The most likely thing to happen would be the denudation of the edges of the basaltic cake first, and then the soft strata underneath, eventually leaving a mountain where there had been a depression before.

Section 1, Plate XII., shows the present shape of the ground, which is entirely detrimental to the "chalk basin" hypothesis; for to get the basalt up to the elevated points at each end, the whole centre must have been filled by at least 1600 feet of basalt, supposing that it was never thicker at the extremities of the section than it is now; and it is in the highest degree improbable that this great thickness would be swept away by the unassisted power of denudation, while the thin parts, as well as the surrounding and underlying soft strata, should be left. On the contrary, we find several isolated hills here still, in consequence of being covered by a protecting cap of basalt.

2. The subjacent chalk is to all intents and purposes of nearly equal thickness throughout; thinning very gradually from east to west. Had it been thrown into its present position previous to the basaltic outflow, we should expect to find it of unequal thickness here and there, from the effects of atmospheric denudation; we should find old ravines and river courses in it, and old escarpments, covered by the basalt; instead of seeing, as we really do, that the chalk and basalt escarpments are one. The whole points to but one conclusion: the chalk formed a great plain of *marine denudation*, cut away while rising from beneath the ocean; on this the basalt was deposited, and the two together were afterwards thrown into the form they now occupy.

3. Lastly. It can be clearly shown that all the most important faults that traverse the district are (in part at least, and this part of considerable magnitude) of post-basaltic date. And as these have had a very large share in the moulding of the existing features of the country, it will, I think, be allowed that a similar appearance could hardly have prevailed beforehand.

On all these grounds, I hold that the chalk basin is itself the result of post-basaltic forces.

V.—*Present and Former Flow of the Principal Feeders of the Lake approximately the same.—The present Watersheds therefore of Pre-Glacial origin.*

It has been shown that the rivers which seem to be most intimately connected with the Lake delta are the Blackwater and the Upper Bann; but it is difficult to prove the existence of either of them in their present course at the early period when the clays were deposited. However, there is no manner of doubt that the materials of the delta were brought from the southwards, and I am inclined to think that it is to a river flowing in nearly the same

course as that now occupied by the Bann that the most of this matter is to be attributed—for this reason:—The clays are highly siliceous and aluminous, but non-calcareous; wherever they have been proved, no calcareous bed has been discovered. Now, the Blackwater traverses for a great part of its course a limestone country, and would, therefore, deposit much calcareous matter,* either from solution on evaporation of carbonic acid, or as undissolved calcareous mud. On the other hand, the Bann, rising in the Mourne Mountains, and flowing over granite, and silurian grits and slates, from its birth travelled through highly siliceous and aluminous rocks† (beginning with the basalt), with hardly a bed of limestone; and here we have all the elements required for the preparation of clays such as form the delta, together with their intervening beds of sand; so that, on the whole, the evidence seems to incline this way. But all this must be a matter of some obscurity, and I can only see my way to its solution “as through a glass darkly;” besides, I must confess that my knowledge of a great part of the country through which these rivers flow is too imperfect to justify me in expressing more than a very speculative opinion. At any rate, the important point is clear as day, viz., the Pre-Glacial existence of the principal feeders of the Lough at the south, as at present, and necessarily a similar watershed; thus showing a conservative state of things, which could not be if, as has been maintained, a mass of ice, with power to remove 2000 feet thickness of solid strata, had since the formation of the Lake passed across it. According to the more advanced school of glacialists, this would have entirely remodelled the face of the country, cutting away hills altogether, or even scooping them into valleys—“larger striæ;” but I trust it will be conceded that the ice-flow in this case has only followed the earlier contours of the ground—no doubt smoothing, polishing, and in some places breaking up and removing, parts of the rock; but by no means having to do with the original carving out of the district.

VI. *Details of the probable Mode of Formation of Lough Neagh.*

During an examination of the coal districts of the county Tyrone, I had certain facilities—information from miners, and others engaged in the collieries; accounts of trial shafts, borings, and workings, &c., in the working out of the fault systems existing there, which otherwise, especially in such a drift-obscured country, must have remained a subject of great uncertainty; and I think it is possible to show a very close connexion between these faults and the causation of the existing physical geography of the Lake basin.

* A recent deposit of calcareous mud is found near its mouth.

† This must be so, as the Triassic rocks rest directly on silurian beds along the valley of the Lagan.

At the same time, it must be stated that any expectation of tracing these faults by inequalities of the ground or Lake margin would but result in disappointment. There is no apparent coincidence, except in one instance, to be mentioned hereafter, which is indeed a very strong one; and all that I stipulate for is, that they were the means of determining the flow of water into, and the removal of *detritus* out of, a certain area, in the first instance.

Fault No. 1.—The principal fault traversing this district is that which forms the north-western boundary of the Dungannon coal-field. It has been traced by me for almost 10 miles, from the western extremity of the coal-field to where it cuts the basalt, and from its great throw it is judged to extend a much greater distance. It is impossible to estimate the amount of its downthrow with any degree of certainty; but it brings down the coal-measures themselves at least 1900 feet thick, against the calp and lower limestone, so that I believe I am under the mark in setting down 2000 feet as a probable figure. It is very possible that this, as well as other large faults in the district, may belong to two periods: a part of the downthrow taking place after the Triassic period, and a further subsidence occurring along that line of weakness after the basaltic outflow. But the shifting of the basalt shows that this last depression must have been very large. The direction of throw is south and south-east.

It appears to decrease towards the south-west, where its traces are lost; but following its general direction to the north-east, it should cross the margin of the Lake at Kiltagh Point, and if continued would join with the great Templepatrick fault on the east side of the Lake, which brings down the basalt against chalk and trachyte. The downthrow of this is to the same side (south-east), and, according to my former colleague, Mr. W. E. L'E. Duffin, has a magnitude of several hundred feet at least. It seems to me, therefore, that we have here one great fault, very deep near the Lough, and gradually dying away S. W. and N. E. If I be right in this surmise, it has a length of over 50 miles, rivalling that one referred to by Professor Hull, F. R. S.,* extending from Colne, in Lancashire, to Leek, in Staffordshire—a distance of about 55 miles.

Fault No. 2.—Parallel in direction to the former, and two miles north of it, is a fault proved as the southern boundary of Annaghone coal-field. A trial-pit on the south of it proved the new red sandstone for 100 yards. From other evidence, and especially the shifting of the chalk outcrop further to the east, I consider that there must be a downthrow of not less than 1000 feet to the south.

Fault No. 3.—Two miles north of the last is another large fault, which I have traced from Grange, south of Cookstown, where it brings the new red beds down against the Permian of Artrea to

* The Physical Features of Yorkshire and Lancashire, &c., "Quart. Jour. Geol. Soc. Lond."

Coagh, where the chalk and basalt are thrown down against the new red marls. The downthrow is to the north and north-west, and its amount can hardly be less than 200 or 300 feet.

Fault No. 4.—Further north, about a mile, and a little north of Coagh, there is a fault running in the same direction as the last, but with an opposite throw, *i. e.*, to the south. Judging from the distance to which the basalt is shifted back, the downthrow ought to be considerable; but the traces of it are lost to east and west. If it continues to the east, as is possible, this, *with the last fault, would form a trough passing very nearly in the position of the deep part of the Lough close to the northern shore.* It is, therefore, worth while to point out this coincidence.

As we go further northwards along the chalk escarpment, numerous other Post-Miocene faults are observed, which doubtless all bore their parts in assisting the shaping of the country; but there are no opportunities of tracing their continuations either way, or of determining the amount of throw. The whole district on this side of the Lake is, however, cut up by post-basaltic faults, themselves of different ages, and even the basalt capping the summit of Slieve Gallion has apparently been brought down against the metamorphic rocks by a fault belonging to one of the latest sets. (See Section 1, Plate XII.)

Along the northern shores of Lough Neagh the structure is necessarily obscure, since the basalt entirely covers the newer formations, and there is accordingly no means of ascertaining the amount of throw of faults, which without question exist there. It will, doubtless, be possible hereafter to trace some of them by means of the ore beds lying in the basalt.

On the north-east is the great fault at Templepatrick, already referred to as the supposed continuation of the coal-field boundary fault; while on the east, and continuing round towards the south along the chalk escarpment, extending along from Black Mountain to Moira, very many faults occur, cutting through chalk and basalt, the general downthrow being to S. W., or *towards* the Lough, and varying from 10 to 300 feet.*

But on this side it is easy to prove that the upheaval into their present basin-shape of the rocks is actually of post-basaltic age. To illustrate this, let us trace the chalk escarpment from the Black Mountain Δ 1272 feet to near Lurgan, about 150 feet elevation—a distance of more than 18 miles from north-east to south-west. It will be found that, in all that distance, the chalk retains much the same thickness of from 50 to 100 feet, the differences being always gradual, and not abrupt. Now, had the chalk been elevated to its present position *before* the basalt had covered it, it cannot but be supposed that the most probable effect of subsequent denudation would be to remove the chalk irregularly. In some places it would be thick and massive, in others altogether absent; and we should expect to

* See Map.

find traces of old river-courses, and other marks of pre-basaltic subaëreal degradation. But such evidences have, I believe, never been observed here, or in any other part of the chalk of Ireland; and I therefore infer that the last denuding effects to which it was subject before the volcanic outflow was a general planing down to a tolerably flat surface, on which the basalt afterwards spread itself; and that the tilting up occurred later, the central depression giving the *chalk*, as well as the basalt, the present basin-shaped dip. The same argument holds good with regard to every other part of the cretaceous district here. Wherever the chalk exists, no matter how elevated or depressed its position, there can be no doubt whatever but that this is due to movements which took place after, and not before, the period of volcanic disturbance. The extent, regularity, and, if I may so express it, conformability, to the basalt of the chalk over an immense area, prove this, and could not be accounted for by any other supposition. It is true the chalk thins out towards the west, becoming but 20 feet thick at Slieve Gallion Carn, and only 3 feet at Craig-na-shoke. But the attenuation is regular and gradual, not abrupt or variable, and is only what might be anticipated in a plain of marine denudation, but certainly is not indicative of the partial and capricious sculpturing of "rain and rivers."

The character of the basalt and chalk escarpment is seen to be similar on the south of the Lake, wherever it is uncovered by the ancient delta. But if there are any post-basaltic faults here, it is difficult to trace them. A probable one may, however, be pointed out. Near Dungannon there is a large fault, bringing down the upper portion of the carboniferous limestone, and helping to preserve the coal-field. It meets the great boundary fault, forming an angle with it, and the continuation of neither can be observed past the point where they should meet. Thus they might possibly be of the same age. The fault referred to is certainly Post-Triassic, as its influence is seen on parts of those rocks. Its throw is *towards* the Lough; and, passing south of it—if it continues so far, and is of post-basaltic age,—it would have had an important effect in determining the features of the country; possibly also in initiating the denudation of the valley of the Lagan.

I have already referred to the long valley extending from the mouth of the Upper Bann, along towards Carlingford. Its level and general direction appear to correspond with those of that north of the Lough, along the Bann; and the impression is conveyed that they are the same valley, expanded in the centre, but forming a kind of axis along which the disturbing forces acted. Towards the north the feature is so marked, that Portlock* has no hesitation in putting it down to the score of post-basaltic disturbances; and he refers to certain depressions in the chalk, &c., along the northern sea-coast, as probably due to the

* "Report on the Geology of Londonderry, &c.," p. 156.

accompanying oscillations. If this view be correct, as seems reasonable, the movement, doubtless, extended southwards, and most likely aided in the production of the other valley. The central depression may be accounted for thus:—The large fault bounding the coal-field shows its greatest known depth at the north-western extremity of the coal-measures, where it cannot be less than 1000 feet; and it dies away at both ends, as proved by the Templepatrick fault to the north-east, while south-west all traces of it are lost. This in itself would form a great dishing up to east and west. The other more northern faults seem to follow this example, so that the north and south steps, and the east and west curvature, would be contemporaneous, and would all agree in forming a great central depression in the very middle of the space which Lough Neagh now occupies. Figs. 3 and 4, Plate XIII., are designed to show how a basin-shaped depression might be formed by such subsidences accompanied by denudation.

The lateral uptilting may have been accompanied by some of the north and south faults known to exist, as well as others suspected, but not as yet verified, along the valley itself.

VII. Denudation of the Country.

To recapitulate a little; it will be seen that the argument is as follows:—After the chalk had been reduced to its present thickness over this large area, but while it still formed the remains of a tolerably flat sea-bottom, the basaltic flow occurred. Upheaval or depression then took place along certain lines, in such a way as to form a large hollow, or depressed space; but this depression did not occur so suddenly as to leave great barriers of rock standing up. Were this so, there would be some difficulty in getting rid of the *detritus*. For denudation must have gone on *pari passu* with the gradual movement, as it always does; and thus, bit by bit, the overlying basalt was eaten away, becoming thinnest around the edges of the flow, as these become gradually highest. At first the course of the water by which the *detritus* was carried off must have been very different to what it is now; and it seems probable that it may have run out to sea by the eastward. For it was not until the conclusion of the disturbances, and after the Lake had assumed its finished proportions, that the southern river, or rivers, to which the clays owe their origin, began to flow. Had it not been so, those beds would themselves have been faulted, and would have received a high dip, instead of being, as they are, continuous and flat-bedded.

The valley of the Lagan was probably commenced to be excavated at the beginning of the elevation of the eastern side of the basin. It was not scooped out before, as the whole country was covered with a thick flat cake of basalt; nor could it have been formed after the entire elevation, for the edge of the basin would prove a complete barrier. It must, therefore, have been produced *during* the elevation; the river, once obtaining the tendency to flow, always keeping deeper than the

adjacent ground, in accordance with the principles laid down in the very able paper by the late Professor Jukes, on the "River Valleys of the South of Ireland."* This valley must, therefore, be of slightly antecedent date to the completion of the Lough Neagh basin, but of the same geological period.

There can be little question but that the denudation over this part of Ireland, during the latter part of the Miocene period, must have been enormous; for not only was the whole of the basalt in many places removed, but also the chalk, together with portions of the lias, new red sandstone, permian, coal-measures, and carboniferous limestone.

If we take points near the Antrim coast, where the thickness of the basalt is known as at Black Mountain, and restore it to what must have been at least its original thickness—say 1500 feet, which is not excessive considering that the adjacent Scottish basalt is still between 3000 and 4000 feet thick, without counting what must have been denuded away—this will bring up the vertical thickness of rock removed in many places to more than 2000 feet, which, in my judgment, must be really under, and not over, the true figure; and this not in one or two circumscribed localities, but over many hundred square miles of ground. For there can be hardly a doubt that a very great part of the country to the west and south of the basaltic plateau was reduced to its present configuration at the same time.† Nay, the whole of Ireland may have then received a great proportion of the features it now presents: for it is not to be supposed that the denuding action was confined to the *North* of Ireland; and there is no reason to suppose that any part of the country was submerged at that time.

Enough has now been said, I trust, to show that the present physical geography of this district belongs to a Post-Miocene and Pre-Glacial epoch; and that, in arriving at this determination, we are largely indebted to Lough Neagh and its clays. There could have been no lake here before the basaltic outflow occurred, for the *physique* of the country was entirely different; but the Lake, with its delta, and consequently much, if not all, of the present face of the country, was in existence prior to the great Glacial epoch; proving beyond a doubt that it was *not* the ice which carved out the hills and valleys around it, but that unsensational yet steady worker, denudation, of course in all its moods and tenses (including frost, air, water, &c.), assisted by certain potent movements of the earth's crust. And here I may be permitted to point out the importance, in inquiries of this nature, of studying the geological structure as well as superficial

* "Quart. Jour. Geol. Soc. Lond.," vol. xviii.

† Professor Hull considers the basaltic area but a fragment of the original surface which extended southwards to Slieve Croob, or the Mourne Mountains, and westwards as far as the Sperrin Mountains, county Derry: "Volcanic History of Ireland" "Journal of Royal Geological Society of Ireland," vol. iv., part 1, p. 27.

appearances of a country. It is, no doubt, possible in some cases that ice has the power of producing hills and valleys of a pitch of 2000 feet; but it is certainly injudicious to apply such a theory to the Lough Neagh district, which was shaped ages before it came under the influence of that agent.*

VIII. *Recapitulation ; or, Summary of Conclusions.*

- (1). That the Lough is of an age intermediate between the Miocene and the Glacial period : viz., Pliocene.
- (2). That it is not a true rock-basin, and has not been formed by ice-action, either of Miocene or subsequent age.
- (3). That it is part of an area of depression, and is due to the existence of one or more series of faults, assisted by sub-aërial denudation.
- (4). That the extensive deposit of clays and sands, with beds of lignite, which are found along the southern shore, and for some miles inland, is the delta of a former large river, which flowed very much in the same course that either the Upper Bann or the Blackwater does now—probably the former.
- (5). That these clays are of considerably later date than the basalt, and that the silicified wood may, with most probability, be referred to the latter deposit.
- (6). By the help of these clays we learn that the existing physical geology, and main features of the surrounding country, were formed to a great extent at a comparatively recent period—that is to say, at some time posterior to the flow of the basalt, but *previous to the Glacial Epoch*; and that the great denudation which has affected at least the North of Ireland belongs to this time.

* It is a curious coincidence that what appears to be the true origin of the Lough, as an area of submergence, is that actually ascribed to it by tradition as occurring within the historical period. Moore refers to this in the well-known lines:—

“ On Lough Neagh’s bank as the fisherman strays,
When the clear cold eve’s declining,
He sees the Round Towers of other days
In the wave beneath him shining.”

I never was so fortunate, however, as to catch a glimpse of these monuments of departed glory.

APPENDIX.*

Fossiliferous Pliocene Clays overlying Basalt, near the Shore of Lough Neagh.

At the time the foregoing paper was written, although I was perfectly satisfied, from cumulative circumstantial evidence, that the Lough Neagh clays were of much more recent date than the Miocene basalt which occurs near the Lake, I had no actual proof to bring forward: the junction of the basalt and the clay beds being nowhere visible, so far as I had an opportunity of examining the district—this comprising all the shores of the Lough, with the exception of a small corner near Crumlin. It was therefore necessary to state fully—even at the risk of tediousness—the reasons why the clays must be considered to be the uppermost, and of Pliocene age.

During a recent visit to this hitherto unexplored locality, accompanying Professor Hull, F.R.S., for the purpose of tracing the eastern boundary of these beds, we were so fortunate as to meet with a well-exposed section showing the clays resting on a denuded surface of basalt. We were also lucky enough to find at this place the only fossils which, with the exception of plants, have yet been discovered in the Lough Neagh clays.

The beds in question occur on the Crumlin River, about a mile from the eastern shore of the Lough, and about $2\frac{1}{2}$ miles from Crumlin village. The basalt is exposed for some distance along the stream, and following it downwards we came upon the following section:—

SECTION IN CRUMLIN RIVER.

(See Plate XIII. Fig. 2.)

	F. in.
A. River gravel and alluvium,	18·0
m. Dark-grey laminated sandy clay,	2·0
f. " " " " full of <i>Unio</i> -like shells,	1·0
m. Dark-grey clay,	1·0
m. Coarse laminated gravelly clay—pebbles of quartz and basalt—resting in pockets and erosions of basalt,	3·0
B. Nodular zeolitic basalt—greatly eroded,	3·0
	<hr/> 28·0

The section is exposed for about forty yards. The clays are visible for some distance lower down the stream, and in one place show well-marked cleavage. The basalt on which they repose was evidently the ancient shore of the Lake. It is greatly water-worn, and the pebbly clays lying on it and in the hollows are clearly shore beds. A

* Added in Press.

little higher up the stream the basalt rises into a bold shore cliff. A deposit of drift disguises the surface indication of this, but in section it is very distinct. Two miles south of this, on the Glenavy River, the basalt presents an exactly similar aspect. The old cliff is very well shown, while a little lower down the Pliocene clays, full of plants and lignite, are found, but the junction is hidden.

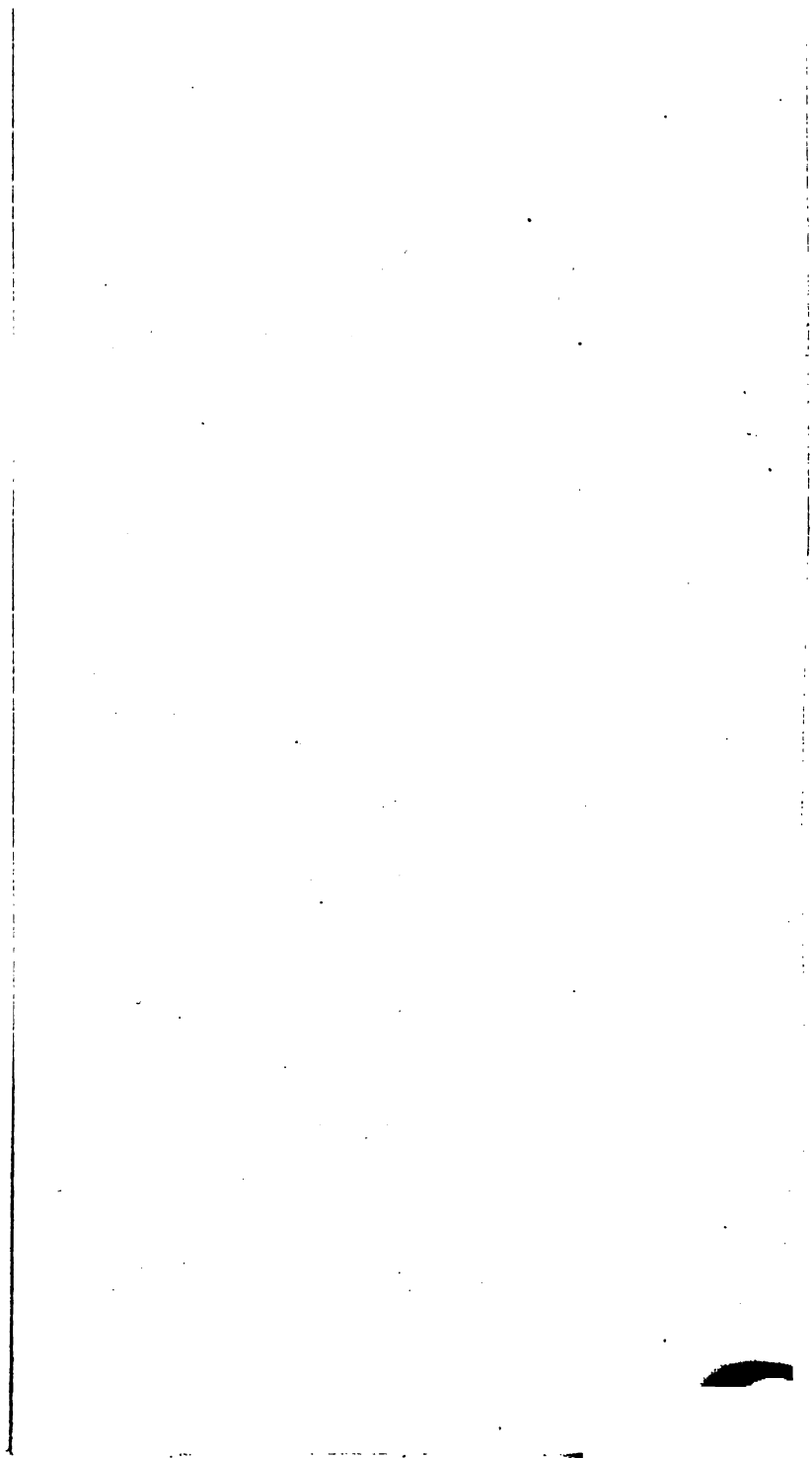
The presence of those ancient cliffs not only serves to mark the former extent of the Lake, which must have been at least double its present dimensions, but also shows that glaciation could not have acted very energetically in that district, since in that event it would have undoubtedly removed all traces of them.

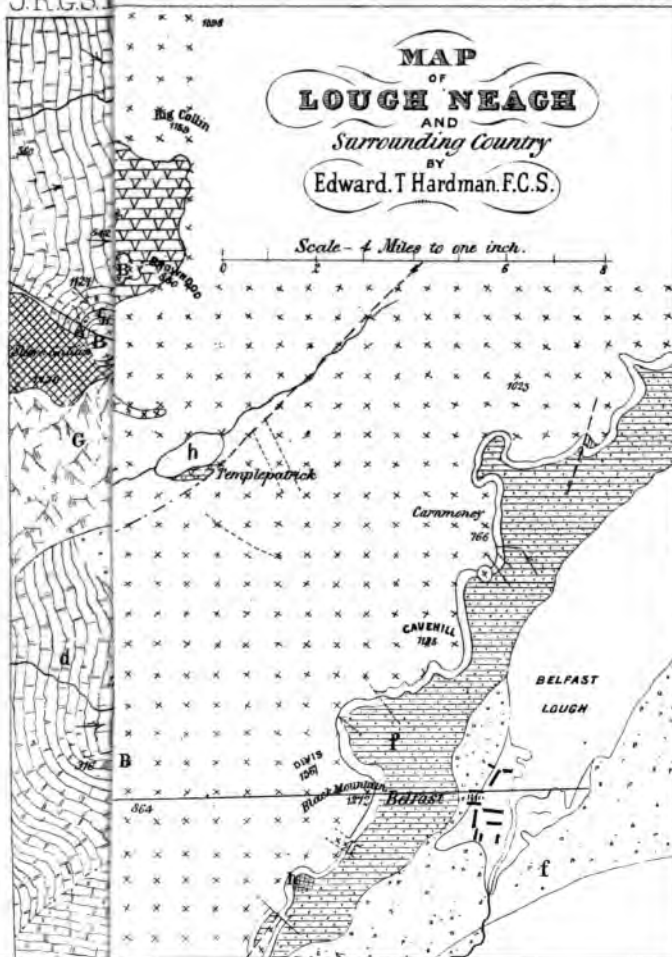
A similar shore and cliff may be seen on the northern margin of Lough Neagh, just under Shane's Castle, Antrim; but the clays do not extend so far north as this, and the basalt is laid bare on the shore, presenting rather a remarkable appearance in some places, and rounded as if by ice (see Plate XIII., Fig. 1). Another old cliff occurs along the south side of the point jutting out by Langford Lodge. Both of these are, however, more recent than the drift.

The Lough Neagh clays had hitherto proved barren of any fauna. I had examined carefully every excavation that had been made in the potter's clay of the south side, but without success; nothing but plants being obtainable. The Rev. Dr. O'Meara—whose valuable researches on Irish Diatomaceæ are so well known, thought it likely that these clays might yield diatoms, and I procured some specimens for him at Professor Hull's request. These I understand gave no result; and it appeared certain, therefore, that no fossils save land plants were to be expected from these strata. It was then with much satisfaction, that while examining the section detailed above, I came on a bed of clay full of shells.

The fossils are mostly confined to a band about a foot thick, and are very abundant. They appear all to belong to a species of *Unio*. Owing, however, to their extremely delicate structure, and the soft and friable nature of the deposit in which they lie, it was very difficult to obtain good specimens, and unfortunately those which I brought away with me received such damage during their transit that it was almost useless to attempt to determine them. Mr. W. H. Baily, F.G.S., to whom I submitted them, is inclined to think that they may possibly belong to a new species. They are not unlike the *Unio Solandri* of the upper Eocene of Hordwell Cliff, Hampshire, so far as external appearance goes.

The shells are extremely thin and fragile, but the structure and markings are perfectly preserved, and the nacreous lustre is still quite brilliant. I have no doubt but that a palæontologist visiting the locality, and having leisure to make a careful examination, would find many perfect specimens capable of determination, and probably other species as well. In the meantime it is right to put the matter on record, seeing that this place is, so far as I know of, the only locality in the British Isles yielding lacustrine fauna of Pliocene date.





J.R.G.S.I.

Fig 1.

N.W.

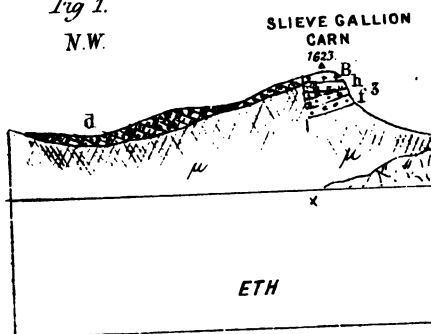


Fig. 2.

Edward T. Hardman delt. et lith.

in *Phocene Ch.*

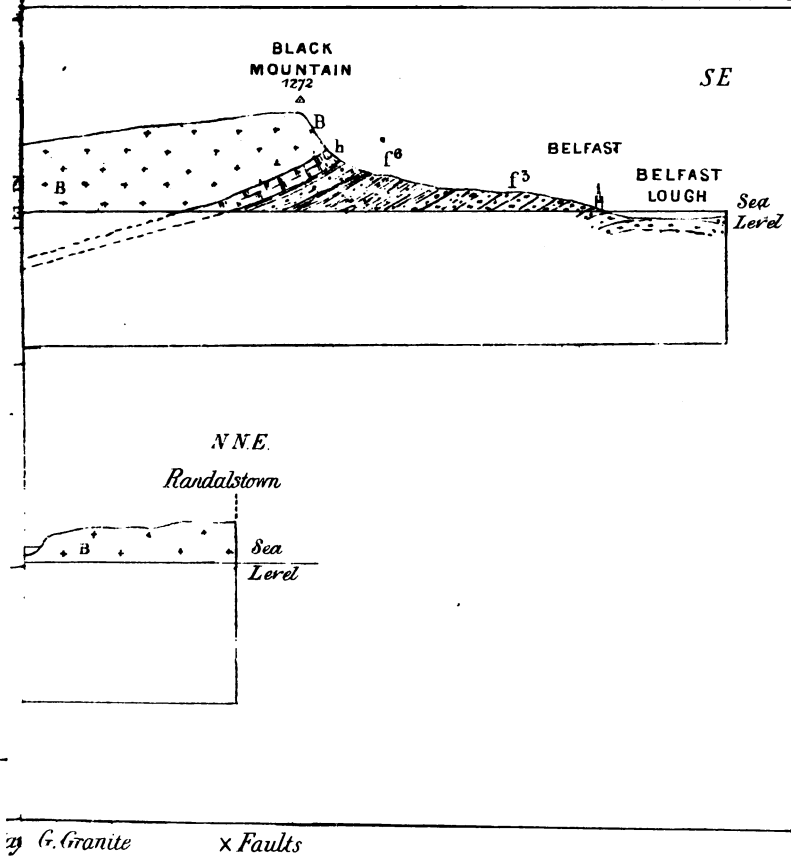




Fig. 1.



Fig. 2.

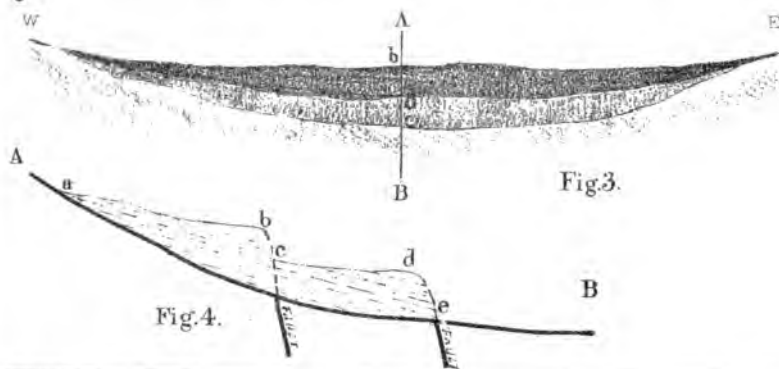


Fig. 3.

Fig. 4.

EXPLANATION OF PLATES XI., XII., AND XIII.

PLATE XI.

Map of Lough Neagh.

PLATE XII.

Fig. 1. Section from Sileve Gallion, across Lough Neagh, to Belfast Lough.

Fig. 2. Section along Lough Neagh from Loughgall to Randalstown.

Note.—It has been necessary to exaggerate the vertical scale of these sections in order to show the details on such a small scale, and the surface-height of the Lough has had to be still further increased to render it visible. Otherwise the sections are correct, having been reduced from others drawn on the natural scale. The author does not wish to commit himself as to the position of the cretaceous rocks as laid down, the dotted lines being merely intended to express diagrammatically the effect of the various faults.

PLATE XIII.

Fig. 1. Basalt Cliff and Beach at Shane's Castle, northern shore of Lough Neagh.

Fig. 2. Section on the Crumlin River.

A. River gravel and alluvium.

m Pliocene clays.

f Fossiliferous band.

B Basalt.

Figs. 3 & 4.—Diagram to show how a lake-basin could be formed by longitudinal faults and contemporaneous denudation.

Fig. 3. Section along line of faults.

Fig. 4. Section across faults at A, B.

b; *c*, *d*, *e*; represent the steps which would be formed by the faults, and simultaneously removed by the action of water, as shown by the dotted lines, the result being a basin N. and S., and also E. and W.

a, *e*, Slope produced by denudation.

XXVIII.—ON THE ORIGIN OF ANTHRACITE: WITH SUGGESTIONS AS TO THE POSSIBLE CORRELATION IN TIME AND MANNER OF PRODUCTION OF THE ANTHRACITES OF SOUTHERN IRELAND, WALES, DEVONSHIRE, AND FRANCE. By EDWARD T. HARDMAN, F. C. S., of the Geological Survey of Ireland.

[ABSTRACT.]

THERE is little to be found in the text-books concerning anthracite and the mode of its formation; and in the few instances where it is noticed, the result is not satisfactory. It sometimes happens that even in the same book, two different and contradictory theories are put forward, evidently showing that some confusion on the subject exists:—one being that anthracite is due to the crumpling of strata; the other, that plutonic influences are the cause of it. Some authors do not refer to it except as a variety of ordinary coal, while others do not even mention it. Nor does it appear that there are any special works on it. I have endeavoured, therefore, to bring together such facts as I could collect with reference to it, and consider that these prove anthracite to be the result of the alteration of ordinary coal by the heat of a mass of molten igneous rock protruded in the vicinity—such being the only theory that suits all cases.

Chemistry of the Changes which Coal undergoes.—Considering coal to be the ultimate result of the alteration of woody matter by the elimination of successive portions of carbon, hydrogen, and oxygen, combined as marsh gas (CH_4), carbonic acid gas (CO_2), and water (H_2O), the transition will take place in about the following order:—Cellulose, or woody matter; peat, lignite, and brown coal; splint coal; hard coal, steam coal; anthracite; and, finally, graphite.

Leaving out the ash, and other accidental ingredients, the constitution of woody matter or cellulose, may be taken as $\text{C}_{36} \text{H}_{60} \text{O}_{30}$ being, a multiple of $\text{C}_6 \text{H}_{10} \text{O}_5$. We shall then have the following series, calculated from various analyses:—

TABLE I.

Cellulose, . . .	$\text{C}_{36} \text{H}_{60} \text{O}_{30}$.
Peat, . . .	$\text{C}_{34} \text{H}_{34} \text{O}_{12}$.
Lignite, . . .	$\text{C}_{31} \text{H}_{30} \text{O}_5$.
Splint coal, . .	$\text{C}_{28} \text{H}_{21} \text{O}_2$.
Hard coal, . . .	$\text{C}_{26} \text{H}_{20} \text{O}_2$.
Steam coal, . .	$\text{C}_{25} \text{H}_{15} \text{O}$.
Anthracite, . .	$\text{C}_{24} \text{H}_8$.
Graphite, . . .	$11\text{C}_2 = \text{C}_{24} \text{H}_{28} - 2\text{CH}_4$.

The following Table will serve to show approximately the manner in which the gases have been eliminated :—

TABLE II.

Loss undergone by Cellulose in passing into various kinds of Coal.

Passing into	CH ₄ .	CO ₂ .	H ₂ O.	C ₂ H ₄ . Olefiant Gas.
Peat . . . Cellulose loses	—	2	13	
Lignite . . . "	1	5	14	
Splint coal . . . "	3	7	14	
Hard coal . . . "	4	8	12	
Steam coal . . . "	4	7	15	
Anthracite . . . "	5	7	16	
Anthracite (coal, altered by strong heat, Sonora), "	3	4	20	2*
Graphite, . . . "	7	7	16	

These are but approximately correct, as, owing to the varying composition of different coals, we could hardly expect more. But the Table seems to show fairly the changes that actually go on. For instance, we know that, in the first alterations of woody tissue, a large quantity of carbonic acid and water are given off, and but little marsh gas. As the process goes on, however, the latter body increases more and more, and is eliminated in a much greater ratio than the other elements. In fact, after a certain time the amount of carbonic acid and water becomes almost too small for estimation,† as is shown by the analyses of the gases from coal mines, which consist nearly entirely of carburetted hydrogen alone. They contain only from 0·7 to 2·10 per cent. of carbonic acid.‡ In the process of time, or by the help of external causes, all the oxygen having disappeared, there remains only carbon plus a little marsh gas, forming anthracite; and, finally, the removal of the last two molecules of marsh gas leaves graphite.

Thus anthracite might result in time from the gradual elimination of the volatile matter of coal; and some of the oldest anthracites may

* A product of the destructive distillation of coal.

† *Vide* Dr. Lyon Playfair, "On the Gases evolved during the Formation of Coal." "Mems. Geol. Sur.," vol. i., p. 475. Also J. W. Thomas, "On the Gases enclosed in Coals from the South Wales Coal Basin, and the Gases evolved by Blowers, and by blowing into the Coal itself." "Jour. Chem. Soc.," Ser. II., vol. xiii., p. 820.

‡ This is well exemplified in Table II., where the loss of carbonic acid is at a stand-still from the splint coal downwards.

have been so formed.* But this will not explain those of the carboniferous and later periods, since beds of the same age, and which have apparently been subject to the same conditions, are found to be in numerous cases anthracitic in one part, and bituminous in others.

In some cases it has been noticed that beds of anthracite are accompanied by flexures, contortions, and dislocations of the strata, as in Pennsylvania, and part of Pembrokeshire, and it has, therefore, been thought that these have effected the change, by allowing readier escape of gases through the fractures and crevices; or by permitting the influx of steam, or other heated emanations, which would aid in driving off the volatile matter. It is a fact, however, that *contorted anthracite coal-fields are rare, while, on the other hand, a much larger proportion of bituminous coals are greatly disturbed and twisted.*

It will be found that, in nearly every instance where anthracite occurs, an outburst of igneous rock, of later date than the anthracite beds, exists either in the immediate vicinity and unmistakably altering the coal, or is protruded sufficiently close to it to warrant the assumption that some of it rises near enough to have effected the change. Full evidence on this point, as well as against the other suppositions, was given in the original paper. A short synopsis must serve here.

Ireland.—Here we have well-marked cases in point:—1st. The conversion of ordinary coal into anthracite by heat. At Ballycastle, county Antrim, a thick bed of basalt has penetrated the coal-measures, and has altered the bed of coal above it to a true anthracite. The beds are not contorted, and though faults occur, the coal is quite unaltered, save in proximity to the basalt.

2nd. The coal-measures at Annaghnoe, county Tyrone, are highly contorted—in fact, inverted; yet the coal here is extremely bituminous.

3rd. In the Leinster coal-field, which, perhaps, contains the purest anthracite of any district, the beds are nearly horizontal; the dip rarely exceeds 5° , and any undulations are most gentle.† The Arigna coal-field in Leitrim lies nearly flat; yet the coal is similar to the steam coal of Wales. Of these two more hereafter.

Scotland.—The few examples of anthracite that are found here are invariably associated with igneous outbursts. The coal-fields so affected are the *Clyde Basin*, *Fifeshire*, and *Ayrshire* coal-fields. The last contains the well-known “blind coal” of Kilmarnock; and in some places the anthracite has been rendered quite columnar‡ by the thermal influence of trap-dykes.

* Dr. T. Sterry Hunt considers that while the alteration is in many cases due to “subterranean coking,” it may often have been the result of decomposition at ordinary temperatures: “Chem. and Geol. Essays,” p. 177.

† The Slieveardagh portion of this coal-field has the strata rolling at high angles, but there is no difference in the quality of the coal.

‡ A specimen may be seen in the Museum of the Royal College of Science, Dublin.

England.—Many of the northern coal-fields are penetrated by trap-dykes, and wherever these have been approached sufficiently near to the coal it has lost its bitumen, and approaches more or less to the character of anthracite, as in parts of Durham and Northumberland; also in South Staffordshire, where the "10-yard coal" has been altered in more than one place to anthracite, by the intrusion of masses of trap. This same coal is in many places contorted, faulted, and crushed, but is never anthracitic under these circumstances.

The Bristol and Somersetshire coal-field is a good example of highly disturbed and contorted coal-measures, containing very bituminous coals, and no anthracite. The disturbances are especially marked along the southern extremity, the coals being often inverted—as in the Nettlebridge Valley. The most fiery seams actually occur in the broken ground, showing that the gases have not had a better opportunity there of escaping than in the more regular parts.

South Wales Coal-field.—This coal-field was once undoubtedly connected with that of Bristol, and like it lies north of, and has been affected by, the great line of dislocation traceable from St. George's Channel to Westphalia.* It is, therefore, but natural to suppose that whatever effect flexuring might have in producing anthracite in the one case, it would have in the other; and that were the anthracite in South Wales due to such action, there ought to be plenty of anthracite in the Bristol district. This not being the case, it is equally natural to consider the South Wales anthracite as not to be ascribable to disturbances. In South Wales, the coal, bituminous on the eastern side, begins to change its character about the Neath Valley, near Merthyr Tydvil, becoming only semi-bituminous. This alteration goes on towards the west until at last in Pembrokeshire only pure anthracite remains. The alteration not only proceeds *westwards*, but *downwards*—that is, at a given point the lowest beds are most altered; or again, the same bed will be most affected to the dip. This shows that, as De la Beche observes†, the alteration can neither be accounted for by original difference in the coal, nor attributed to contortion and dislocation; for, as he points out, in some places neither coals are disturbed at all, whilst in others, as at Herwaun and Pyle respectively, the bituminous beds are actually far more disturbed than the others. Were fissures or dislocations efficacious in allowing the escape of gases, we should have the topmost parts of the beds de-bituminised, not the lowermost. Everything points to the influence of internal heat exerted over the western part of the field, the effect becoming less and less upwards and outwards, as the distance from the source of the heat increased. De la Beche favoured a similar view, considering the coal-measures to have been let down by

* See Prestwich's Report on the Somersetshire Coal-fields.—"Coal Commissioners' Report," vol. i.

† "Mems. Geol. Sur.," vol. i., pp. 217, *et seq.*

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a large fault, and afterwards re-elevated. This, however, does not account for the *gradual* transformation, as the transition would then be abrupt. I am rather inclined to consider that the source of heat must have been brought near the coal-measures, as by a protrusion sufficiently close of a mass of molten rock, which, without appearing at the surface, would, nevertheless, metamorphose the coal.* Professor Hull also advocates the theory of direct thermal influence.†

It is remarkable that, a few pages further on, De la Beche refers to the occurrence of trappean and granite rocks in Pembrokeshire, in the neighbourhood of Rosemarket, and the northern arm of Milford Haven, of more recent age than the coal-measures, and whose presence quite obviates the necessity of supposing a special subsidence, as it is not illogical to suppose them to be the surface indications of a deep-seated mass of rock. De la Beche considers these to correspond with the granitic eruptive rocks of Dartmoor, which we now know to be of post-carboniferous age.

Devonshire Culm-Measures.—On the south of Bristol Channel the carboniferous rocks extend southwards to Launceston, and the upper beds, containing culm, have long been referred to the coal-measures. They rest both north and south on Devonian rocks, and form an irregular basin. They are greatly contorted towards the south, and are there penetrated by the Dartmoor granite, to which is evidently due the crumpling, as well as the alteration of the strata into schists and slates, and the conversion of the coals into culm (impure anthracite).

The Dartmoor granite is but a portion of a very large outburst, which is seen at intervals over the greater part of South Devon and Cornwall. The granite of Lundy Island is doubtless also a boss of it, rising to the north, and not unreasonably far from the culm district, while it may also be connected with the granitic rocks of Pembrokeshire. The upthrust of these different bosses might well have thrown off the strata, north and south, and so produced the basin shape and crumpling of both the Devonshire and Pembrokeshire coal-measures.

The granite extends towards the west in Cornwall, where its greatest mass is seen; but is not found much to the east of Dartmoor. This may account for the western part of the Welsh coal-field being altered, while the Bristol coal-field is not affected; also, for the anthracitic character of coals in the south-west of Ireland, supposing its influence to extend so far.

France, Belgium, Italy, &c.—In these countries there are many examples similar to those cited above. In France the numerous small coal-fields, east of Auvergne, contain for the most part an-

* That such may take place without actual eruption at the surface, Jukes has shown very clearly, "Manual of Geology," edited by Geikie, p. 244.

† "Coal-Fields of Great Britain," 3rd ed., pp. 89, 90.

thracite, and are connected with outbursts of igneous rocks. The districts lying around the mountains of the Forez have been specially subject to igneous action, and the coals have been altered to anthracite, as in the region extending from Vichy to St. Etienne. Here, in the valley of the Sichon, the coal-bearing rocks are penetrated by porphyritic rocks, and much altered: the coal being anthracite, and the alteration being so far carried that, until Murchison proved these beds to be of carboniferous age, they were supposed to be silurian.

In Dauphiné and Savoy anthracite is found associated with altered schists and sandstone of carboniferous age, together with serpentine and hornblendic rocks. There is some controversy on the true age of these beds, and the mode of their occurrence; but the weight of evidence appears to be with those who hold that the igneous and metamorphic rocks are of mesozoic age; and Elie de Beaumont and Sismondi considered that the section in Mount Cenis tunnel upholds this view. The alteration of the coal would be thus accounted for.

Anthracite also occurs in the departments of Mayenne and Sarthe; in the latter being associated with schistose carboniferous rocks. Granite of apparently later date occurs in the vicinity.

Possible Relations of the Anthracites of Ireland, Wales, &c., and France.—In this connexion there is a very remarkable fact. It may be merely a coincidence; but all the same, it deserves notice.

If we take a map of Europe, and draw a line through the Leitrim coal-fields (steam coal), and through the semi-bituminous portion of the South Wales coal-field, and prolong it south-easterly into France, we find that all the coals on the north-east are bituminous, while all those on the south-west are anthracitic. Moreover, it is possible to draw a second line parallel to it, which will pass through not only the principal and most highly anthracite districts in the countries in question, but also the principal outbursts of later granite. In Ireland, the Leinster coal-fields; Wales, Pembrokeshire, through the culm of Devonshire, taking Lundy Island and Dartmoor on the way; then on through the granite rocks of Cherbourg, through Mayenne and Sarthe, south-east into Vichy, St. Etienne, and Isère, and very nearly touching the debatable district of Dauphiné. The closeness with which this line follows the post-carboniferous plutonic rocks, and the anthracitic districts, is extremely curious, and certainly seems to warrant the throwing out of a suggestion that there is just a possibility of there having been at one time a very extensive upthrust of heated rock along the line indicated, coming at intervals near the coal-measures. It is true that this would give an extremely long hidden granitic axis; but this can be no objection, seeing that it would be some 500 miles short of the granitic axis of the Ural chain, according to Murchison's map, while the length of the granitic steppes of southern Russia would suffice to reach from Leitrim in Ireland to some distance south of the anthracite district of Sarthe. So that there is nothing absurd in conceiving the extension of plutonic action

over such a distance as I have pointed to. Similar instances are seen in the older metamorphic rocks of the Appalachians, which extend for many hundred miles. The chief difficulty is whether all the plutonic rocks on the line I have referred to are of the same age. This I have at present no means of ascertaining, further than that I believe it may be fairly taken for granted that they are all of post-carboniferous age. In some cases, as that of Dartmoor, it is impossible that we shall ever know more than this.

It seems almost more than mere coincidence that anthracites extend not only along this line, but also are more decidedly altered towards the south-west, precisely in the direction of the lateral extension of the granites, as shown in Cornwall; and although I am willing to curtail my theory of its fair proportions, and waive that part of it which applies to France, in the absence at present of more positive evidence, it certainly appears not unreasonable to apply it to the anthracites of Devon, South Wales, and Ireland.

North of France and Belgium.—The coal-fields of the North of France and Belgium, forming the elongated basin stretching from near Calais to Aix-la-Chapelle, a distance of about 210 miles, serve to show very conclusively that flexures and crushing are of themselves powerless in effecting the alteration of coal. Nearly everywhere along this basin the coals exhibit a most extraordinary amount of flexuring. In some cases this is so complicated that the same shaft will go through one seam of coal several times. The published sections of these coal-fields indicate that the seams lie in a series of gigantic zigzags, folded over and over, proving that a very great crushing force must have acted here. Were anthracite due to such causes, there ought to be abundance of it in these coal-fields. But the only anthracitic coal that is found is obtained from the *lowest beds* at Mons, there being here a gradation downward from "fat" or bituminous coal at top, to "lean" or steam coal at bottom. As the Mons coal-field is the deepest in the whole basin, the measures reaching a thickness of 5,674 feet at least, it is possible that at some time before the upper measures and newer strata were denuded, the temperature may have been sufficiently high to affect these coals. Had the crushing anything to do with the alteration, it is the upper seams that would have been affected. It is clearly either to internal heat, or to the partial action of some igneous rock in the neighbourhood, that the exceptional phenomenon here is to be attributed. It may be mentioned, that there are porphyritic rocks between Liège and Mons;* but their age I am unable to state. If newer than the coal-measures it would prove a very interesting fact.

Saarbrück.—It is certain, however, that in the Saarbrück coal-field there are extensive igneous intrusions, especially along the

* See "Quart. Jour. Geol. Soc.," vol. vii., p. 6, On the Porphyry of Belgium, by Delesse. Age, or mode of occurrence, not stated.

northern outcrop, which have altered the coals there.* It is no impossible that they may rise still further north at Mons.

Westphalia, Saxony, Silesia, Hanover, and Hesse.—The Westphalian measures are very highly flexed,† on the continuation of the line of disturbance extending from Bristol; yet the coals are all bituminous, with the exception of the Alexander seam, which is anthracitic. In Saxony, at Chemnitz, the coal-measures are penetrated by permian porphyries, &c.,‡ which accounts for the alteration of the "*Russkohle*" to a partial anthracite. The coal strata of Silesia are invaded by masses of porphyry and other igneous rocks;§ and here again we also find anthracite. At Waldenburg the effect is plainly seen.|| The small coal-field of Osnabrück also contains anthracite, produced by the action of igneous rocks;¶ while in Hesse, on the Meissner, the basalt, where it has come in contact with the Tertiary brown coal, has converted it into anthracite.

Styria.—In the Stangen Alps anthracite has also been produced from the coal by igneous action.

Russia.—One of the most important European anthracitic regions lies in the very extensive coal district known as the coal-field of the Donetz, in southern Russia. Here a similar state of things exists to that which is observed in Wales, only in the contrary direction. The coals, which are highly bituminous on the west, or north-west, become gradually anthracitic towards the other extremity of the coal-field; and not only that, but the accompanying strata, are indurated and altered.**

Along the south-west runs the great granitic axis of the southern steppes; consisting of granitoid gneiss, quartzites, schists, &c., penetrated by large masses of igneous rock. Murchison declares that the igneous eruptions have continued along that line posterior to the carboniferous era; attributes the contortions and high inclinations of the carboniferous rocks to the elevatory agency of the axis; compares the gradual loss of bituminous matter as analogous to the same phenomena in South Wales; and, finally, refers to the remarkable coincidence between the line of anthracitic coal and the crystalline axis of the steppes, and suggests, "that in their subterraneous prolongation, the igneous rocks there rising to the surface may have converted the superjacent ordinary coal into anthracite, and have indurated the associated grit, sandstones, and schists."

On the flanks of the Ural Mountains the carboniferous rocks are upheaved, hardened, and altered; the millstone grit in places becoming

* Hull: "Coal-fields of Great Britain," p. 335.

† *Vide* "Die Steinkohlen Deutsch. Geinitz." Pl. XV.

‡ Cotta, "Rocks Classified, &c.," p. 309.

§ Hull, *op. cit.*, p. 343.

|| Cotta, *op. cit.*, p. 334.

¶ *Ibid.*, p. 336.

** Murchison's "Geology of Russia," vol. i.

quartzite. A few thin coals occur. The analysis of that at Vashour proves it to be anthracite. The granitic axis of the Ural is post-carboniferous; it may be of the same age as that of the southern steppes.

India.—Most of the coals in this peninsula are bituminous. In the Mohpani coal-field, Central Provinces, the character of the coal varies, however, from highly bituminous to anthracite of a friable kind. The measures are much disturbed, and are overlaid and penetrated by large masses of basaltic rock of Tertiary age,* to the presence of which the alteration of the coal is undoubtedly due.

America.—In every instance in which anthracite occurs on this immense continent, it can be shown that there are outbursts of more recent igneous rocks sufficiently near to account for the change, or that the coal-measures themselves are altered in such a manner as could only be attributed to igneous action of some kind.

The Great Appalachian Coal-field is often cited as an instance of the coincidence between anthracite and disturbed coal-measures; and it is true that there is a remarkable, but *exceptional*, agreement between the two here. It will be remembered, however, that such contortions exist abundantly in very many bituminous coal-fields, and their connexion with anthracite is really so very rare that they can only be regarded as accidental in this case. The coal-field, which is some 180 miles broad, and several hundred long, is evenly bedded towards the west, the coals being bituminous; towards the east, the beds begin to roll, and are finally contorted, and the coal gradually becomes anthracite. It happens, however, that all along the eastern border of the coal-field large dykes of trap-rock appear, extending from the Connecticut valley, where they are extremely numerous, through Pennsylvania, into North Carolina. Cross branches proceed from these, in one case extending from near Philadelphia to the borders of the Schuylkill arm of the coal-field. These are all of Post-Triassic age, seeing that they penetrate the new red sandstone; and when we consider what an immense distance they run longitudinally, it cannot be unphilosophical to regard their lateral extension as of proportional magnitude. It is not at all improbable that some of this trap penetrated sufficiently near the coal-measures to drive off the volatile matter.

Massachusetts and Rhode Island.—This highly metamorphosed anthracite district is clearly the north-eastern extension of the Appalachian coal-field. The measures have been in some cases completely altered to quartzites and schists, and the coal even to graphite. The beds are only occasionally contorted. It appears likely that this locality was a focus of igneous action. The great abundance of the mesozoic trap-rocks in Connecticut, and extending through New Jersey into Nova Scotia, favours this view.

* Col. Meadows Taylor, M. R. I. A., &c., On the Coal-fields of Central India. "Jour. Roy. Geol. Soc. Ir.," vol. iii., p. 129.

Arkansas.—Here there are anthracites and steam coals. The formation is "level and undisturbed."* No igneous rocks are found nearer than 60 miles; but Macfarlane considers these may come sufficiently near the surface to have expelled part of the volatile matter.†

Newer Anthracites of America.—Triassic Coal: North Carolina.—In the Deep River section the measures are penetrated by large dykes, or masses of igneous rock; and the coal graduates from bituminous to anthracite, and even to graphite, which is associated with incipiently fused sandstone.

Mexico.—At Los Bronces, Sonora, Triassic coal has been found altered into anthracite by an eruption of porphyritic rocks.

Tertiary Coals of America.—At many places on the Pacific coast, as at Alaska and Coos Bay, Tertiary lignites are altered to good bituminous coals—at the former place to a most beautiful and brilliant anthracite—by the intrusion of igneous rocks, by which also the strata are greatly disturbed. On the other hand, many sections on the Pacific Railway show the lignites to be greatly contorted without any alteration.

Finally, at Santa Fé, New Mexico, the outflow of a mass of trap has altered lignite over a large area into a valuable and compact anthracite. As is not uncommon, this has received a columnar structure.

Conclusion.—I submit now that the evidence is all in favour of the igneous theory, as against that of flexures; so much so, that we should be warranted, from the mere presence of anthracite in any district, in predicting the existence of an igneous rock somewhere near. The evidence I have given, which comprises all the anthracite in the world whose mode of occurrence is known, is simply overwhelming on this point.

Although it cannot be *proved* in the case of the southern Irish anthracites, there is no other way of accounting for their production.

Other writers have already suggested a similar theory with regard to particular and limited districts. It has been my aim to show that it may be applied almost universally.

* Macfarlane: "Coal Regions of America," p. 341.

† *Op. cit.*, pp. 449 500.

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XXIX. — IRISH DRIFT. SUB-GROUPS—AQUEOUS AND GLACIAL DRIFTS.

By G. HENRY KINAHAN, M.R.I.A., &c.

[Read, November 8, 1876.]

In a previous communication to the Society, attention was directed to the Meteoric drift; in this it is proposed to speak of the *Aqueous* and *Glacial drifts*.

AQUEOUS DRIFT.

Aqueous drift, proper, is drift which has been washed, sorted, and deposited in and by water; but it is often found to graduate into glacial or into meteoric drift; so that in some cases it is impossible to state the precise mode of formation of a certain mass of drift which might, at first, be supposed to be purely aqueous.*

Aqueous drifts may be *Fluviatile*, *Lacustrine*, *Estuarine*, or *Marine*. Estuarine and marine drifts are usually classed together; but in this Paper they are kept separate, as in some particulars the estuarine deposits are quite distinct from open sea accumulations. They may partake of the nature sometimes of lacustrine, and sometimes of fluviatile drifts; it often happens that they are not well washed or sorted, and they form more or less sloping accumulations; and besides they may contain terrestrial organic remains.

In typical aqueous drift, ice-dressed fragments often occur, if the drift has been formed out of an older glacial drift. Some pebbles and blocks of rock are so hard that the water action and the accompanying friction of one rock fragment against another cannot grind out the ice-marks; † while in some cases the pebbles may not have been travelling long enough to become much water-worn. Sometimes dressed fragments may have dropped into the aqueous drift from icebergs, or from cliffs of glacial drift, or even may have rolled down from higher ground. These dressed fragments are more usually found in fluviatile, lacustrine, or estuarine drift; but in some places they are not uncommon in marine drift. In the latter case, they occur more frequently in fine deposits—such as clays, marls, and the like.

In addition to the typical aqueous drifts belonging to the four varieties just mentioned, there are others which partake, more or less, of the nature of glacial or meteoric drift. They must, however, be

* All, or nearly all, drifts are aqueous, if we extend the meaning of the term to its fullest extent; as ice is frozen water, while all meteoric drifts, except those that are solely due to wind, are accumulated by rain and runlets.

† The estuarine accumulation along the Ovoca river, Co. Wicklow, between the village of that name and Arklow, is, in a great measure, a "paving-stone drift," or shingle. This shingle was evidently formed from the glacial drift which is found in various places in the marginal and river cliffs. In the estuarine shingle, more or less of the fragments are ice-marked; while in some places, especially near the margins of the flats, the contained ice-dressed fragments are at least 75 per cent. of the whole.

included in the aqueous drift, as they were evidently arranged during accumulation in water. One of this kind was described some time since as *Glacialoid*, or glacial-like drift ("Geol. Mag.," March and April, 1874). This is like glacial drift, in that many, and sometimes nearly all, of the contained blocks and fragments are ice-dressed, while the matrix is a clay or sandy clay. It is therefore evident that the materials that now form this drift were, immediately before their deposition therein, enveloped in ice; but that the drift was arranged, as we now find it, in and by water, is also evident, as it is distinctly stratified, and often more or less sorted. Probably this drift has resulted, in some instances, from the droppings from icebergs; as we know that at the present day icebergs have a tendency to collect and melt away at certain places, such as the banks of Newfoundland; while in other cases it may have been formed from the detritus dropped from an ice-sheet that extended some distance into the sea, or from an ice-foot. This glacialoid drift is very considerable in some portions of Ireland, especially amongst and near some of the hill-groups, such as those of West Mayo and Galway.

These accumulations of glacialoid drift often contain more or less marked inliers of typical aqueous drift (silt, sand, gravel, &c.), often forming mere partings, but sometimes being conspicuous in lenticular masses. In some districts, these inliers will be on various horizons; but in other localities, such as the coasts of Mayo and Galway, they occur on the same horizon for miles (Memoirs Geological Survey, Exps. to Sheets 83, 93, &c). When these inliers are on different horizons, the mass of the glacialoid drift has usually the same general character throughout; but when on a single horizon, the drifts above and beneath usually, if not always, have certain distinctive characters. These distinct characters would seem to suggest that in such places the ice-sheet or glacier retreated for a time, and that, when it again advanced, the characters of the contained fragments and blocks were more or less changed.

Land-slips from cliffs of drift may sometimes give rise to curious, perhaps even misleading, phenomena. The fallen masses may sometimes be mistaken for drift deposited *in situ*, and they often push about, disturb, and otherwise distort the already regularly deposited drift, often leaving it in most fantastic forms. On the south coast of Wexford the results of such slips may be seen among the shelly drifts that were accumulating when the sea was about 100 feet higher than at present; while at the Bar of Lough, on the same coast, a similar phenomenon is going on at the present day.*

* My colleague, J. G. Goodechild, F. G. S., has figured contortions in drift which are apparently due to such slips: "Quart. Jour. Geol. Soc. Lond.," February, 1875. A somewhat similar process may be seen now going on in the old quarry a little S.E. of Kingstown Harbour. The excavation is being filled with the dredgings from the harbour, whilst at intervals, wagon loads of ashes from the

Fluviatile drift seems to be of different ages; and it necessarily occurs at various levels, not only as we pass from one river course to another, but also as we follow the line of one and the same river course. Dana has shown that during the Glacial Period there must have been, in many valleys, rivers and streams under the ice sheet; and the fluviatile drift accumulated by such rivers is now overlaid by glacial drift formed from the detritus in the superincumbent ice. Clarence King points out that this is illustrated amongst the dying-out glaciers of the western slopes of the Rocky Mountains. Over the glacial deposits, thus formed, there may be other fluviatile drifts deposited at various heights by the rivers that have been in existence since the ice disappeared. Fluviatile deposits are, of course, very different in different places. In steep places shingles and gravels are formed, which, however, are rarely as clean as those made by the sea, since they are deposited during freshets which do not last sufficiently long to thoroughly wash the detritus laid down by them. On gentle slopes the sluggish stream will deposit fine materials. If the river valley immediately above a flat or a lake is steep, the stream will deposit gravel and shingle near the upper end; and fine sand, silt, or mud often mixed with peat in the other parts, of the same flat or lake. In all the large Irish rivers, and in most of the small ones, the detritus carried down by the waters is deposited in the flats and lakes which the rivers pass through, scarcely any of it getting into the open sea, and very little even into their estuaries.

In many places in Ireland the fluviatile drifts accumulated since the Glacial Period are now more or less covered up by drift due to the slipping or weathering down of adjacent cliffs, or by accumulations of meteoric drift carried down on to them by rain and runlets. In some cases this rearranged drift is, in aspect, very like glacial drift, and may be mistaken for it by inexperienced observers.

Lacustrine drift, also, may be of both pre-glacial and post-glacial ages. The pre-glacial drift has not often been recorded in Ireland. It might naturally be expected to be rare, as while the ice sheet was passing over the country it would catch up and carry away most of the already existing loose accumulations. Some, however, seems to have been preserved. The clays, with lignite, in the Lough Neagh basin are pre- or intra-glacial, as also the pipeclay with lignite near Cahir, county Tipperary. In the Boleynendorrish river valley near Gort, county Galway, there are beneath glacial drifts peaty leaf beds, which may be lacustrine. Similarly circumstanced deposits may be found elsewhere, as, for instance, the peat bed in the Newtown Colliery, Queen's Co., probably also lacustrine. Some of the post-glacial lacus-

ships are tilted into it. The latter, when first thrown down, form regular layers; but afterwards, when other matter is thrown upon them, their lines of deposition are twisted, contorted, and broken up, similarly to those of the sands, clays, and gravels, found among the glacialoid drift on the south coast of Wexford.

trine drifts have been left dry either by change in level of the land, or by the deepening of river channels, and such might be mistaken for part of the regular drift of the country.

The *Estuarine drifts* seem to be more important than usually supposed, and parts of them are not easily distinguished from fluviatile drift, with which they are often confounded. The characters of the two are very similar; both often containing terrestrial fossils, and forming more or less sloping terraces.

Different portions of an estuarine deposit may have very different characters; the littoral accumulations partaking more or less of the nature of the littoral accumulations of the open sea; while the deep water deposits are more often like those of a lake.

The littoral deposits of the open sea undulate more or less slightly; but those of an estuary usually slope downwards from its upper end to its opening into the sea. In the estuary of the Shannon the rise of the mean tide is more than four feet higher at the city of Limerick than it is at Loop Head; while in the Bristol Channel the mean tide rises 27 feet more at Chepstow than at St. David's Head.* The margin of the sea, if taken as that of the mean high tides, is 13 feet higher in Cardigan Bay than at Courtown, Co. Wexford. The deep water deposits, also, of an estuary have always a greater or less slope seaward. Thus in the fiord called Killary Bay (Cos. Mayo and Galway) there is a fall of 70 feet in a distance of nine miles from Leenaun to Inishbarna. These bottom accumulations, should the sea retire from them, would form sloping gravel terraces similar to those that are usually called river gravel terraces. As, however, this subject has been fully entered into elsewhere, it is unnecessary to dwell upon it here.†

In many places the ancient estuarine drifts are found to be more or less covered by glacialoid and other meteoric drifts derived from neighbouring cliffs of older drift. The presence of these overlying materials, mixed occasionally with contributions from land-slips has, in some cases, led observers to classify some of these estuarine gravels as intraglacial drifts.

Marine drifts, unlike the other aqueous drifts, may cover vast areas; but the marginal and deep water accumulations are, in general, more or less dissimilar.

The purely marine littoral deposits on the open sea-board of Ireland are always well washed, and are usually also sorted. They range from fine sharp sand to shingle, sometimes containing blocks tons in weight. In some places these blocks are water-worn and rounded; but under exceptional circumstances, as in places on the west coast of Ireland, but more especially on the Aran Islands, Galway Bay, the blocks are semiangular. Deep sea accumulations are

* Tide Heights and Raised Beaches, "Geol. Mag.," dec. ii., vol. iii., p. 78.

† "Valleys and their Relations to Fissures, &c." (Trübner & Co.), pp. 188 to 194.

generally fine muds, sands, and gravels, except in those places where there are strong currents, or where foreign materials, as from icebergs and the like, have been dropped into the sea.

The raised sea beaches of Ireland differ, in some respects, from the present. In the latter we find accumulations ranging from fine sand to coarse shingle; but the coarse shingle containing blocks tons in weight seems to be absent from the raised beaches; yet there are places in which we might have expected that such shingles would have been formed during the respective times when the sea was 25, 100, and 300 feet higher than at present.*

The variations in the level of the sea since the Glacial Period have made various complications in the marine drifts—for when the sea was deep over some particular area fine deposits would there accumulate; and when the sea became shallow at that place, shingles would be laid down over the fine materials. Sometimes the fine graduate into the coarse deposits; but very often the latter lie on a denuded surface of the former.

A good example of this coarse shingle, lying on a denuded surface of gravel, can be seen in a small raised beach at the mouth of the Shanganagh river, Killiney Bay, Co. Dublin; and in other places on the east coast the shingles of the 25 and 100 feet beaches are found on denuded surfaces of older gravels and sands. In the interior of the country, especially in the valleys of the Barrow and Nore, we find these paving-stone shingles well represented. Here, as the sea became shallow, strong currents formed in the narrows between the Carlow and Castlecomer hills, and between the Castlecomer and Kille-naule hills, which denuded the older gravels, and deposited on them the paving-stone shingles. To the west of the Shannon, in the Co. Galway, we find these paving-stone shingles heaped up in eskers; as near Killimor, and in the parish of Tynagh, while in the vicinity of Kiltormer the typical esker gravels graduate into half-washed drifts. In the counties of Mayo and Roscommon the esker ridges are in many places principally made up of this "paving-stone" type of drift; in which from 20 to 50, and in some places 60 or 70 per cent. of the fragments are more or less glaciated—a good example is the Ballyhaunis esker, Co. Mayo. These paving-stone shingles have been classed as glacial drift because they contain some glaciated fragments, and graduate into clayey drift. But if they be glacial, then the previously mentioned estuarine shingle of the Ovoca river and the esker gravels should be considered glacial, as also the shelly sands, marls, and clays of the counties Wexford and Wicklow; since all contain more or less glaciated blocks and fragments.

* There are, indeed, places in Clare, Galway, and Mayo, where there are peculiar piles and ridges of blocks that may possibly have been ancient beaches. At higher levels both in the Galway hills (550 feet) and in the Kerry hills (1800 feet) coarse shingles, apparently of marine origin, have been found in a few places. "Geol. Survey of Ireland," Exps. to Sheets 94 and 183.

The marine drifts, as well as the lacustrine, may be divided into pre-glacial and post-glacial, or those below, and those above, the glacial drift. The pre-glacial marine drift, as the ice sheet was passing over the country, must have been usually caught up and carried away; and in the low country, in the numerous sections exposed in the railways and other cuttings, it is very unusual to find stratified drift between the glacial drift and the underlying rocks. This is so even in localities where the rocks do not seem to be ice-dressed, as in parts of Galway, Derry, Tyrone, &c., where the glacial drift is separated from the underlying rocks by a mass of more or less angular rock *debris*.

Among the hills, however, gravels and other stratified drift under the boulder-clay are not uncommon; as, for instance, on the Castle-comer table-land, on Slieve Gallion, Co. Derry, and in many other districts in Ireland.

In the Arctic regions there are intra-glacial aqueous drifts being formed at the present day by the alternate retreat and advance of the ice on the sea coasts. Records of such changes during the Glacial Period might be expected to be preserved in the Irish drift; yet there seems to be a great paucity of such evidence. As pointed out by the late J. Beete Jukes, F.R.S., and the officers working under him, there are in places two distinct varieties of glacial drift, especially in the neighbourhoods of some of the groups of hills—one containing well-dressed blocks and fragments, many of which are far travelled, while the other contains many semi-angular blocks and fragments, all being more or less local; the matrix of the former being usually much more clayey than that of the latter. Between these two different drifts we might have expected a more or less well-marked series of intra-glacial aqueous drifts; but such does not occur. Sometimes, indeed, there may be between them a thin parting, a few inches thick, of clay or fine sand, or even occasionally a lenticular bed, swelling in places to a few feet thick; but such are always rare and of limited extent. In the vicinity of some of the hills—as on the west of Slieve Phelim—there are gravels that seem to be lenticularly interstratified with glacialoid drift; but whether the latter is an undecided form of glacial drift, or a re-arranged drift, it is difficult to determine.

The pre-glacial marine drifts may possibly be all of one age; but it is just as likely that some of them may be littoral accumulations, formed when the waters of the sea stood for a time at different levels; more especially, as pointed out in the "Memoirs of the Geological Survey of Ireland," as there are in the different hill groups, miles apart, well-marked cliffs, at certain different heights, which seem to have originated from marine denudation.

The post-glacial marine drifts present more or less well-marked terraces at certain definite elevations,* namely, about the 300, 100,

* In the Dublin and Wicklow mountains there are the shelly gravels described by the Rev. M. H. Close, up to the exceptional heights of from 1000 feet to 1200

and 25 feet contour lines. These gravels have been already described elsewhere: * it is therefore unnecessary to treat of them now.

Of the post-glacial marine drifts, the oldest, or "Esker sea drifts" (*i. e.*, those that extend up to about the 300 feet contour line), as they extend over the greatest area, are often found graduating from typical into the paving-stone shingle, rocky drift, or the glacialoid drift. These gradations have been described in the "Memoirs of the Irish branch of the Geological Survey;" also in the Papers previously referred to. The gradations may be seen in the following places, *viz.*, in the vicinity of Tyrrell's Pass, and on Croghan hill, Co. Westmeath; on the north slopes of the Castlecomer table-land; in the neighbourhood of Timahoe, Queen's Co.; in the pass between Slieve Bloom and Slieve Phelim, King's Co. and Tipperary; in numerous places in the counties Galway, Roscommon, and Mayo, &c. (see Exps. Irish Geol. Surv., Sheets 115, 116, &c.) In the valleys of the Nore, the Barrow, and the Suir, there are beautifully defined terraces of not only the 25 feet, the 100 feet, and the 300 feet gravels, but also of newer accumulations, which in places graduate into, and are intercalated with, glacialoid drifts, or merge into glacial drift.

GLACIAL DRIFT.

The typical and genuine glacial drift occurs in unstratified masses. As glacial drift is so intimately connected with both the meteoric and aqueous drifts, it has necessarily been mentioned frequently already.

There are in Ireland two distinct varieties of glacial drifts; † the lower and older of which has been called, in the Government Survey Memoirs, "Boulder-clay-drift," and the upper or newer, "Boulder-clay," or "Moraine-drift." Where both of these varieties occur together, near the hills, one seems to lie directly on the other, as in no place has any regular or continuous system of intervening aqueous drift been found. ‡ In the numerous sections exposed in the railway and other cuttings throughout the country no such aqueous beds appear; although in a very few places, as previously mentioned, there

feet. As these contain shells belonging to species now inhabiting the adjacent seas, it seems to suggest that the gravels are post-glacial. But if they be so, why are they found at these heights on this portion only of the range of hills, while to the south of the hills they do not occur above the 300 feet contour line?

* Memoirs, Irish branch of the Geological Survey "Journal Geological Society of Dublin," vol. x; "Journal Royal Geological Society of Ireland," vol. i.; "Geological Magazine," vol. ii.; dec. ii., vol. i., &c., &c.

† In a former Paper on drift laid before the Society, I suggested that the older drift was due to a general ice sheet, and the newer to systems of glaciers around certain centres. In that Paper, these different drifts are minutely described (Notes on some of the Drift in Ireland, "Journal, R. G. S. I.," vol. i., part iii.)

‡ In the early days of the Geological Survey of Ireland it was supposed that there were middle gravels separating the upper and lower glacial drifts. Twenty years ago, however, this theory was questioned by the late Mr. J. Beete Jukes; while subsequently it was abandoned, as both this observer and the officers working under him found it untenable.

may be thin partings of clay or sand, or thicker lenticular patches of these, of limited extent. Such partings and patches, however, are never continuous, and are probably due to layers and streams of water that flowed between the underneath drift and the ice to which the upper glacial drift is due; similarly to what is occurring in many places at the present day in North Europe and North America. As these drifts have been so often described, it is now only necessary to refer to some disputed particulars connected therewith.

Because gravels and sands surround some of the drift hills in the counties of Tyrone and Derry, they are said to penetrate them in horizontal layers, although in no place in the various cuttings through adjoining hills can such intra-glacial gravels be found. Neither can they be found in any of the numerous railway cuttings in the province of Ulster. If "Middle-Gravels" did exist in these counties, it is scarcely possible that the railways should only pass through the hills in which none such occur.*

At Killiney, Co. Dublin, it has been said, there are two glacial drifts with an intervening aqueous shelly drift. This section is continuous along the coast to Bray; and if it is followed only a little way towards the south, past the valley of the Shanganagh river, it will be found that the supposed "upper glacial drift" is one of the well-known clayey members of the aqueous drift of the east of Ireland.

Farther southward, in the railway cutting immediately south of Bray Head, there is said to be a typical section showing glacial drift between and above shelly gravels. In this locality there is an accumulation of glacial drift massed against the Cambrian rocks of Bray Head, and from it there proceed three or more tongues of a clayey drift that dovetail into the shelly gravels. These tongues, however, all die out to the south, and seem to me to be due to the weathering of an ancient cliff of glacial drift, the *debris* from which became interstratified with the gravels accumulating at the base of the cliff, like what is going on in numerous places round the coast line at the present day. On the coast between Ballinesker and Blackwater, Co. Wexford, we have the results of a similar weathering; masses of glacial drift protrude up into the gravels and marls, and from them extend small tongues and irregular portions of glacialoid drift.

Furthermore, on the coast section of Bray Head we find, at the base of these gravels, a breccia identical with the basal bed of the esker gravels of the counties Wicklow and Wexford, which can be traced very continuously from Wicklow Head, round the south-east coast, to Bannow Bay.

In the Co. Wexford, at Castle Ellis, there is said to be a glacial drift over the "Manure," or shelly sand. I have visited all the sand-pits in that country, and in none of them could I find an upper glacial

* The Dungannon tunnel was made through one of the drift hills around which gravels are found up to the 300 feet contour line; yet no bed or beds of gravels occur in the interior of the hill.

drift, although in some there is a clayey drift over the shelly sands, but which is evidently due to the washing from the high ground to the northward. There are rarely any glacial fragments in it.

In the valleys of the Barrow and Nore an upper glacial drift is said to be very common. This supposed upper glacial drift is exactly the same as that already described by me as "paving-stone shingle,"—an aqueous drift associated with the other varieties. This paving-stone shingle of the valleys of the Barrow and the Nore, and of the valley of the Suir, is associated with each of the differently-aged gravels which respectively reach up to the 25, 100, and 300 feet contour lines, and its only qualification to be classed as glacial drift is that some of the contained fragments are ice-scratched; but, as previously mentioned, so are many of the fragments in the paving-stone shingle of the eskers of the counties Galway, Mayo, and Roscommon, in the gravels of the Ovoca flats, and in recent shingles in innumerable places, all of which, if this theory holds good, must be also classed as glacial.

Although there is no system, in the low lands, of aqueous beds between the upper and lower glacial drifts, yet in some of the hills there seem to be well-marked instances of such a deposit. None of these, however, have been proved to be continuous even in one group of hills; while some of them are unquestionably not so. Water-formed gravels beneath, and apparently above, glacial drift, have been observed in various places in the Cork, Kerry, Clare, and Galway hills; some, however, have more the aspect of fluviatile or lacustrine than of marine drift. In Slieve Gallion, Co. Derry, there seem to be gravels between two glacial drifts; those at Kennaght, previously mentioned, are sharp and clear, as if marine. On the Castlecomer table-land, Kilkenny and Queen's counties, it has been proved by the pit sections that in many places there are two distinct glacial drifts (boulder-clay-drift and moraine-drift) which are usually separated by aqueous drifts. These aqueous drifts, however, are not always continuous; as in adjoining pits, they may be at different levels, or in some they may be absent. Moreover, they rarely seem to be of marine origin, being usually silt, book-clay, or the like, very like fine deposits in shallow lakes or sheets of water that may have intervened between the new ice and the old boulder-clay-drift. Similar disconnected accumulations of intra-glacial aqueous drift have been observed among the other groups of Irish hills; but rarely do they appear to be of marine origin, and in no place do they seem to form a regular system.

In some localities in the glacial drift, but more often in the boulder-clay-drift than in the moraine-drift, there are pipes and lenticular and irregular masses of gravel and sand. Some of these may be due to cracks and shrinkage fissures in the ice, similar to those mentioned by Kane and other Arctic explorers; whilst it is very difficult to account for others. Among many other instances that might be mentioned, some remarkable masses of sand in the boulder-clay were exposed in the recent railway cutting through the Monument Hill, Phoenix Park, Dublin.

XXX.—ON THE OCCURRENCE OF MAGNETIC OXIDE OF IRON AT KILBRIDE,
COUNTY WICKLOW. By CHARLES R. C. TICHBORNE, Ph. D., F.C.S.,
M. R. I. A.

[Read, November 8, 1876.]

THE following Paper is a short account of a find of iron ore, chiefly magnetic, occurring in the parish of Kilbride, county Wicklow, and on the property of William O'Byrne, Esq., the present member for the county. The apparently extensive vein of ore runs from north-west to south-east, and lies a little north of lat. $52^{\circ}55'$, between that latitude and $52^{\circ}56'$, and between $6^{\circ}7'$ and $6^{\circ}8'$ west longitude.

My object in bringing this subject before the Royal Geological Society of Ireland is twofold. In the first place, I desire to place on record the position of the vein, of which there is no notice in the maps of the Geological Survey. This fact is rather curious, as there are numerous surface indications scattered over the ground for two or three miles, besides traces of what had evidently been old workings in the district.

The original explorers were evidently hovering about the prey; but as they were not working on any scientific or methodical plan, they seem to have missed the find. These old workings resemble quarry-holes. There is no recollection of the working of the ore amongst the oldest inhabitants; but occasionally old iron implements are turned up, which, from the rudeness of the construction, would appear to have been home-made. The iron, however, is of excellent quality.

My second object is, that possible instalments to the mineral resources of Ireland should be carefully fostered, and no more appropriate Society for this purpose could be fixed upon than the Geological Society of Ireland.

The ore differs very much in character, according to the parts of the mine from which it is procured; thus the surface ore is loose, friable, and more or less spongy in its nature, but never in any case does it resemble the ordinary bog-iron of this country. It is, in fact, perfectly free from any organic remains. As the vein is further pursued in a vertical direction, it becomes more compact, until we arrive at a very dense ore, having a specific gravity averaging $4\cdot37$.

First determination,	.	.	.	.	.	4·31
Second (piece containing Fe_2O_3),	.	.	.	.	.	4·43
Average,	.	.	.	.	.	4·37.

This last characteristic justifies us in describing it as a specimen of massive magnetite, although, as will be seen from the analyses, it contains an excess of ferric oxide. All the specimens are more or

less attracted by the magnet, and are uniformly so when coarsely powdered.

It is almost perfectly soluble in hydrochloric acid, without the evolution of chlorine.

The more friable portions seem to have a different composition from the dense variety; and it is very probable, as this lies on the surface of the vein, that it contains surface drainage, and other extraneous matter.

A very soft and black portion contained manganese. The following two analyses represent fairly the character of the ore, and are selected as the two most varied in character:—

Specimen, friable and very dark in Colour.

Magnetic oxide,	40·10
Ferric oxide,	22·03
Oxide of manganese,	2·05
Alumina,	6·70
Arsenic (trace).	
Lime and magnesia,	2·60
Silica,	4·01
Phosphoric anhydride,	1·20
Sulphuric anhydride,	1·40
Water combined,	3·40
Moisture,	16·51
	<hr/>
	100·00

Solid Ore, sp. gravity, 4·31.

Magnetic oxide,	72·49
Ferric oxide,	15·30
Oxide of manganese (trace).	
Alumina,	3·33
Arsenic,	0·01
Copper (trace).	
Lime and magnesia (trace).	
Silica,	3·64
Phosphoric anhydride,	0·20
Sulphuric anhydride,	0·30
Sulphur,	0·15
Water,	1·03
Combined water,	2·55

Whether this ore will pay for transit is a question of great importance, but hardly suitable for discussion in the "Journal of the Geological Society." In considering, however, the difficulty and expense of working ores which have to bear the burthen of transit, it should be borne in mind that magnetic oxide is one of the richest ores we have, except hematite. Thus the following percentages of metallic iron in different

species of ore are averages calculated from the analyses published in Watt's Dictionary of Chemistry :—

Red iron ores, average of 7 analyses,	62.37	p.c. Fe.
Magnetic ores, " 6 "	53.30	"
Brown iron ores, " 24 "	42.44	"
Spathic iron ores, " 82 "	33.18	"
Clay iron ore " 24 "	33.35	"
Wicklow ore (dense variety), . . .	63.00	"

About 20 tons of this ore have been forwarded to Staffordshire, and have been smelted with the most satisfactory result. It is reported that it gave a pig-iron of first-rate quality. Magnetic iron ore is frequently found containing a large quantity of silica, and such ore is almost worthless for smelting purposes. Thus a magnetic ore from another source, which contained the large percentage of 56 of magnetic oxide, was found to be unfit for smelting, owing to the large percentage of silica which in this case exceeded 20 per cent. This objection also frequently applies to the Brown ores also.

As regards this vein of magnetic oxide, there can be little doubt that it is of aqueous origin. Its stratified appearance in many parts suggests this in a striking manner; moreover, small microscopic crystals of pyrites being occasionally observed disseminated through these ores, and the silica being found in the free state, are to my mind proofs conclusive. When dissolved in hydrochloric acid, the silica is left as a white crystalline deposit. The ore sometimes contains fine veins of crystalline quartz running through it. Ebelmen, Kuhlmann, and others, have proved that fine specimens of magnetic oxide may be procured by igneous processes; but there can be little doubt that the present deposit is the result of the action of water, for the reasons given above. The question then suggests itself, how are such veins formed? Also we naturally ask by what chemical action or influence is the deposit determined? The Bog deposits of iron so frequently found in this country are, no doubt, the result of the weathering of pyrites, and the production of a soluble ferrous salt in the first instance. But at first sight there would appear to be a difficulty in the way in conceiving the formation of a magnetic oxide from a ferrous salt without the aid of a precipitant; and lime, although present in the loose substance, is, no doubt, due to recent surface drainage, because some specimens of the magnetic oxide proper give hardly any trace of lime salts. One specimen being very compact only gave 0.02 per cent. of Ca, and the district is remarkably free from limestone. It is well known that the result of the oxidation of a ferrous salt in the presence of water is the production of a ferric salt, and never magnetic oxide. If a partially oxidized solution is boiled so as to produce a basic precipitate, that precipitate is still a persalt, and the intermediate oxide is not deposited, although ferrous salts are still in solution. But I have found that such is not the case under pressure. If a solution of ferrous sulphate is left to oxidize by atmospheric influence, peroxide is gradually deposited. If

after this oxidation has progressed some time it be boiled, ferric oxide is deposited in the form of a basic salt. If, however, such a solution be placed in a sealed tube, and particularly if we facilitate the deposition of the basic salt by the addition of an alkaline salt such as potassium sulphate, a dense black precipitate is determined upon the application of heat under atmospheric pressures. This precipitate presents all the appearance of dense anhydrous magnetic oxide of iron, and is susceptible to the action of a magnet through the sides of the tube. I therefore think we are justified in viewing the deposit at Kilbride, and similar deposits, as owing their origin to the changes produced by thermal influences under pressure on partially oxidized solutions. Probably most of the immense beds found in Canada and elsewhere owe their origin to similar causes.

In the Geological Survey maps, and the Memoirs of the Geological Survey, sheets 130, the position of this vein is described as felspathic ash.

In the foregoing notice I have avoided making any speculations, or allusions to the facilities for working this ore, or its commercial aspects; but if I have omitted doing so, it must not for a moment be supposed that I do not think its working feasible; but I have considered it desirable before a Scientific Society to confine myself to pointing out the position of the vein, of which there is no published record, and to deal alone with the chemical, and other scientific bearings of the subject.

XXXI.—DESCRIPTION OF A FOSSIL SPIDER, *ARCHITARBUS SUBOVALIS*
FROM THE MIDDLE COAL MEASURES, BURNLEY, LANCASHIRE. By
REV. SAMUEL HAUGHTON, M. D.

[Read, November 8, 1876.]

MR. HENRY WOODWARD first described the fossil spider, *Architarbus subovalis*, in the "Geological Magazine," September, 1872, vol. ix., No. 9, and figured the specimen found in the ironstone of the Coal Measures of Lancashire. Mr. Woodward's specimen is shown in fig. 1, magnified four times.

Mr. Daniel Morris, of the Grammar School, Burnley, found last year, and presented to the Museum of Trinity College, a more perfect specimen of the *Architarbus subovalis*. This is shown in fig. 2, drawn to the same scale as Mr. Woodward's figure; completing the legs, which are almost altogether wanting in Mr. Woodward's specimen.*

* Fig. 2 is copied from a pencil restoration of the legs drawn by Mr. Woodward for Mr. Morris.

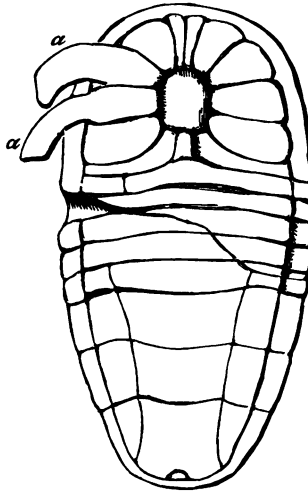


Fig. 1.

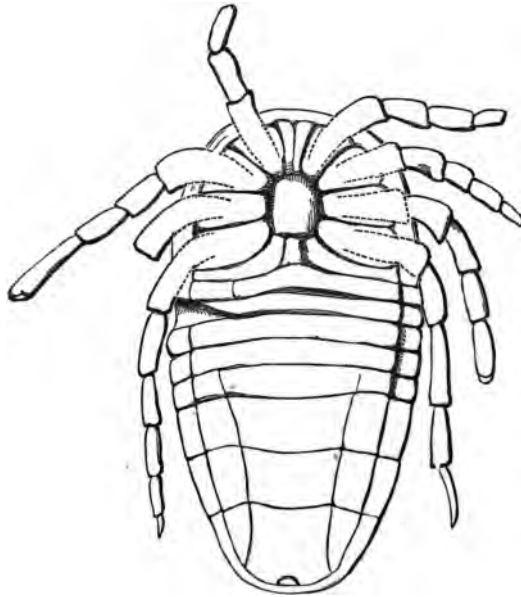


Fig. 2.

Fossil Spider, *Architarbus subovalis*, from the Middle Coal Measures, Lancashire.

XXXII.—ON THE UPPER LIMIT OF THE ESSENTIALLY MARINE BEDS OF THE CARBONIFEROUS SYSTEM OF THE BRITISH ISLES, AND THE NECESSITY FOR THE ESTABLISHMENT OF A MIDDLE CARBONIFEROUS GROUP.
By Professor EDWARD HULL, F.R.S., &c., Director of the Geological Survey of Ireland.

[Read, December 13, 1876.]

[ABSTRACT.]

In this Paper the Author endeavours to show the equivalent stages throughout the British Isles of the members of the Carboniferous system, and divides the whole into successive stages from A to G. Thus:—

Stages.	Name.	Locality.
G	Upper Coal-measures,	Lancashire, Denbighshire, &c.
F	Middle,	England, Scotland, Ireland.
E	Lower, or "Gannister" Beds,	England, Wales, Ireland.
D	Millstone Grit,	England, Scotland, Ireland.
C	Yoredale Beds,	England, Ireland, Lower Coal-field of Scotland.
B	Carboniferous Limestone,	England, Ireland, Scotland.
A	Lower Carboniferous Slate Grits and Conglomerates, Lower Limestone Shale, }	England, Ireland, Calciferous Sandstone of Scotland.

These beds are identified both by position and palæontological remains over the whole area, and lead to some important results. Rejecting the evidence of fish and plant remains, which are inconclusive, the Author finds that there is a strong palæontological division between stages E and F, the fauna of the one (E) being essentially marine, that of the other (F) essentially estuarine, or freshwater. The lists of species have been extracted from the "Memoirs of the Geological Survey," the determinations being those of the late Professor E. Forbes, Mr. Salter, and Mr. Baily. The Author of this Paper is responsible for the determination of the stratigraphical position of the beds from which the species have been obtained.

He finds that there are about seventy-four species and thirty-seven genera of marine forms in Stage E (Gannister Beds, or Lower Coal-measures), of which thirty-three species, and all the genera, come up from the Carboniferous limestone, but only four or five species pass up into the overlying Stage F (Middle Coal-measures); indicating a strong palæontological break.

Again; of eight marine species found at rare intervals in Stage F (Middle Coal-measures), four are peculiar to this zone, and the remainder are common to it and Stage E. The remaining species belong to the genera *Anthracosia*, *Anthracomya*, &c., which some authorities regard as of freshwater, others as of estuarine origin; they probably may be of either. These genera pass into Stage G.

These differences, together with some evidences of a stratigraphical break between Stages E and F, combined with the natural relation-

ship between stages C, D, and E, are so striking that the author submitted they should be recognised in the classification of the beds, and he proposed to establish a "Middle Carboniferous" division, to include all the stages, from the Yoredale (C) to the Gannister Beds (E) inclusive. This stage would be essentially marine, while the term "Upper Carboniferous" would be restricted to the stages F and G, which are shown to be essentially estuarine, or freshwater. The term Lower Carboniferous would remain as at present to designate the Carboniferous Limestone and basal beds of the system, stages A and B.

The author, in conclusion, showed from the writings of Continental palæontologists that the marine stage E can be identified on the Continent, in Belgium, France, and Germany; a band with *Goniatites* and *Aviculo-pecten*, &c., occurring about 100 feet above the base of the coal-measures; while, as we learn from Geinitz, the molluscs of the coal-formation generally belong to the genus *Unio* (*Anthracosia*), so that this remarkable division, with its marine fauna, has had a range as wide as the British Isles and Western Europe, and marks the upward limit of the essentially marine conditions of the Carboniferous system.

[NOTE.—This Paper, of which the above is an abstract, will be published *in extenso* in the "Quart. Journ. Geol. Soc., Lond.," 1877.]

XXXIII.—ON GRAPHIC FELDSPAR, FROM CO. DONEGAL. By REV. SAMUEL HAUGHTON, M.D., Professor of Geology in the University of Dublin.

[Read, December 13th, 1876.]

THIS specimen of Graphic Orthoclase was sent to me by Mr. Robert W. Armstrong, of the Belleek Pottery, Co. Fermanagh. It is used largely in the china manufactory. Its chemical composition is as follows:—

		Oxygen.	
Silica,	66.50	34.53	
Alumina,	18.50	8.64	
Iron peroxide,	0.00	—	
Lime,	0.84	0.24	} 2.60
Magnesia,	0.00	—	
Soda,	1.15	0.29	
Potash,	12.25	2.07	
Loss by ignition,	0.20		

99.44

This analysis denotes a mixture of quartz and orthoclase; and using the known oxygen ratios of orthoclase (1 : 3 : 12), we find the

oxygen used for orthoclase to be

31·20 from the protoxides,
34·56 „ alumina.

Mean, 32·88

This gives at once the mineralogical composition of the rock—

Quartz, 4·7 per cent.
Orthoclase, 95·3 „
100·0

XXXIV.—ON ELVANITE, OR WHITESTONE, FROM MIDDLETON HILL, LONGNOR HALL, SHREWSBURY. By the REV. SAMUEL HAUGHTON, M.D., Professor of Geology in the University of Dublin.

[Read, December 13, 1876.]

THIS specimen of Elvanite, or Whitestone, was given to me by Mr. Robert W. Armstrong, of the Belleek Pottery Works, and was supposed to contain a large quantity of lithia. The following analysis disproves this supposition, but shows the rock to be a most interesting elvanite, as it consists of albite and quartz, to the exclusion of orthoclase. I am not aware of any similar rock existing in Great Britain or Ireland.

Chemical Composition.

		Oxygen.	
Silica,	72·80	37·80	
Alumina,	17·20	8·04	
Iron peroxide, . .	0·16	—	
Lime,	0·89	0·31	} 2·55
Magnesia,	0·14	—	
Soda,	8·14	2·08	
Potash,	0·92	0·16	
Loss by ignition, .	0·20	—	
	100·45		

This analysis denotes a mixture of quartz and albite, with an amount of oxygen employed as albite silica, of

30·60 from the protoxides,
32·16 „ alumina,

Mean, 31·88

From which we deduce—

Quartz, = 15·6 per cent.
Albite, = 84·4 „
100·0

XXXV.—ON THE DISCOVERY OF TRIDYMITE IN THE TRACHYTE PORPHYRY OF CO. ANTRIM. By Professor A. VON LASAULX, of the University of Breslau. Communicated by Professor E. HULL, F.R.S.

[Read, January 10, 1877.]

THIS rare form of Silica was discovered by Professor von Lasaulx, during a visit made to the Trachyte quarries at Tardree Mountain, Co. Antrim, in the autumn of 1876, and the discovery was communicated to the author in a letter dated December 19, 1876, from which the following is an extract:—

"There are two little discoveries I have already made. I have found in the 'quartz-rhyolith' of Tardree Mountain a great many little crystals of Tridymite, a mineral, I think, entirely new to Great Britain [the British Islands]. The rock is so very rich in Tridymite that I dare believe it a real Tridymite Trachyte, like some of the Andesian rocks of Süd-Amerika."

Specimens of the new mineral sent to the author by Professor von Lasaulx were exhibited at the meeting. They were observed to occur in little drusy cavities in the rock, in the form of small hexagonal tables, in groups generally of threes, giving rise to a stellate appearance, and of a slightly yellowish colour. The name has been given to this form of Silica by Vom Rath in allusion to the compound forms of three individuals. [Vorgetr. Ch. Ges. Bonn, 1868, quoted by Dana. "Syst. Min.," 5 edit., p. 805, also Dr. Reynolds' "Mineralogical Tables," p. 26, 1871.]

XXXVI.—ON MICROSCOPIC STRUCTURES IN TACHYLITE FROM SLIEVENALARGY, CO. DOWN, IRELAND. By FRANK RUTLEY, F.G.S., H.M. Geological Survey.

[Read, March 14, 1877.]

DETAILS respecting the mode of occurrence of this Tachylite have already been published by Mr. G. H. Kinahan in the "Geological Magazine."* At his request I have examined the rock microscopically, and now lay the result, imperfect though it may be, before this Society.

The magma or ground-mass of the rock is essentially a glass, presenting under a magnifying power of about 120 diameters a finely shaded or stippled appearance, which, by transmitted light, imparts a pale reddish-brown colour to it: under higher powers, however, it appears of a slightly greenish tint. Within this glass lie a vast

* Decade ii., vol. ii., p. 426.

number of what at first sight seem to be opaque irregularly-shaped grains, mostly approximating to spherical forms; these, however, are seen at times to be somewhat translucent at their margins, where, of course, their sections are thinner, while in other places, where the section retains a still less thickness, they appear throughout to be composed of fine dusty matter, and exhibit a strong reddish-brown and sometimes a greenish colour. It should be observed that the glassy magma where it fringes these granules is of a clearer tint, in fact almost colourless, these clear borders showing none of the stippling which characterises it in other parts. From this it would appear that the fine dust which constitutes the stippling has segregated around certain points, thus giving rise to the dark grains, while the consequent abstraction of this dust from the glass, in the immediate vicinity of the points of segregation, has produced the clearness of the magma where it surrounds these bodies. That in the first instance the dusty matter was more or less equally distributed seems probable; and had there been no segregation of it in the manner described, I have little doubt but that a section of the rock under those conditions would have appeared perfectly opaque when examined microscopically; a circumstance not uncommon in Tachylyte. I base this supposition also upon the fact that the rock now under consideration is in some parts of the section so densely packed with these opaque-looking grains, that only here and there a few translucent lacunæ of the glass-magma are visible (fig. 5), thus proving, even in a small section, less than an inch in diameter, how unequally the dusty matter is distributed, while it also shows that an equal distribution of this dust would have rendered the entire rock opaque, or nearly so, even when cut in thin sections. I will not occupy the time of the Society with quotations, but will merely refer to the description of the microscopic characters of the Tachylyte from Bobenhausen, given in the late Hermann Vogelsang's last work "Die Krystalliten," in which similar bodies are spoken of as "roundish, irregularly-shaped lumps or masses." These, he observes, are the most numerous, but he also notes the occurrence in the same rock of stellate forms consisting of similar matter, resembling some of the crystallites seen in furnace slags. He states his conviction that these crystallites (and we may consequently infer that he intended also to include the "irregularly-shaped masses") do not consist of magnetic iron, but of a glassy silicate, adding, however, that it is not improbable that they contain that mineral in a finely-divided state. He also cites the opinions both of Zirkel and Möhl, the former regarding these bodies as ferruginous glass ("*eisenreiche Glasgebilde*"), the latter as magnetic iron. Vogelsang's objection to this last opinion is that they appear brown and translucent, characters which he states are never present in magnetic iron even in the most finely divided state. I need hardly say that this objection seems to me to be a perfectly just one, always providing that the magnetite be in an unaltered condition. I may remark that the rock now under consideration strongly attracts the magnetic needle, but this is due to

numerous little crystals of magnetite which are disseminated in it, and which lie in the dark parts of the section. The part of the rock delineated in fig. 5 would have shown them in great numbers, had it been suitably illuminated. They are also indicated in fig. 2, which represents a marginal portion of a dark part of the rock, where they are sparsely distributed. If the dark bodies just described be identical with those described and figured by Vogelsang (and to judge from the figures given in his book they *are* identical), it would then seem that the opinions both of Vogelsang and Zirkel were perfectly applicable to these dark bodies; and we have evidence, as shown in fig. 2, that crystals of magnetite are present in the dark portions of the rock (really, the lighter portion when a polished surface of the rock is viewed by reflected light in the ordinary way), and they exist in some parts in very considerable numbers. In the same section which we are now discussing there occur some green, yellow, and white or colourless bodies, their forms suggesting at first sight that they are filled-up vesicles. The yellow and green ones show feeble double refraction and a somewhat radiate structure. The green matter seems to be glass, consisting of a ferruginous silicate possibly allied to glauconite. Now, as we have evidence that magnetite is present in some portions of the rock, let us consider how far we may be justified in assuming the presence of a mineral resembling glauconite in composition; bearing in mind that although the former is an anhydrous oxide, and the latter a hydrous silicate, still the facilities for the development of hydrous silicates are by no means precluded in vitreous rocks of this kind; and, although glauconites are very variable in composition, still, in an analysis of magnetite by Schwalbe, and in many analyses of glauconite by Haushofer,* there is a community in the oxygen ratios for protoxides and peroxides in the two minerals. Potash, which is an essential component of glauconite, does not, however, occur in magnetite, while of course the percentage composition of the two minerals will not bear any comparison; yet we may safely expect to find alkalies present in a vitreous rock of this kind, as not only potash and soda, but also alumina, magnesia, lime, &c., and even a little protoxide of manganese and titanous acid are cited in the analyses of Tachylite by Schnedermann, Gmelin, and Delesse. The foregoing statements do not by any means prove that the green substance which occurs in the Tachylite of Slievenalargy is glauconite, but they show the possibility that it may be some substance more or less closely allied to that mineral. Until its true nature can be ascertained, it is perhaps as well to be content with calling it a green, ferruginous glass, while the yellow matter which occurs under similar conditions may also be regarded as a ferruginous silicate, in which the contained iron is possibly in a different state of combination. In both of these substances there is a tendency to fibrous or pseudo-crystalline structure, which has brought about a little devitrification in those parts. The colourless glass inclosures show no devitrification so far as their

* Dana's "System of Mineralogy," pp. 151 and 463.

general mass is concerned, but they are usually bordered either by the yellow or green substance. From any or all of these different coloured lacunæ what appear to be cylindrical rods, such as those shown in figs. 1, 3, 4, and 6, are seen here and there to be protruded. In some cases it is difficult to say whether some of these rods have originated from lacunæ of this kind, or whether they have existed independently in the general glassy magma, as they are frequently cut short by the planes of section, so that their origins and terminations are not to be ascertained. In fig. 4 we have, however, an instance in which a lacuna of yellow glass is partially traversed by a band which presents a more strongly crystalline or devitrified appearance than the rest of the vesicle. From the small dimensions of the drawing, compared with the amplification necessary to render the structure intelligible, I have been unable to show the lower end of this band, which appears to terminate within the vesicle, while the opposite end, as shown in the drawing, is protruded for some distance into the surrounding glass magma. Sometimes these rods run in straight lines, but appear to follow no definite common direction. Sometimes they are seen to run directly at right angles to one another, but I have not yet observed any instances in which they intersect. At other times they are strongly curved, and occasionally are bent at a rather abrupt angle, as shown in one of the rods in fig. 3. Now and then they appear to swell out at certain points; in other cases they anastomose, bifurcate, or ramify in a curious manner, as indicated in fig. 7. In fig. 6 a constriction is seen near the termination of one of them, while a series of small cube-like bodies are arranged along a central line in the rod. I cannot venture to speculate on the causes to which these diversities of form and arrangement are due; they only seem to indicate the absence of unequal pressure in any one definite direction in the rock. They indicate the existence of no condition of fluxion, such as one meets with in flows of obsidian, pitchstone, and perlite, and I am therefore content to figure and merely describe them, leaving others to speculate on the causes upon which their varied mutual arrangement and configuration hinge. They seem at times to bear some resemblance to certain, much smaller, cylindrical bodies which I described some time since as occurring in an obsidian stream at Rocche Rosse in the Island of Lipari,* still the analogy is by no means very striking. Occasionally these rods are represented by little else than green, granular matter, forming strings, often describing elliptical or circular tracks (figs. 1 and 3), which impart to the stone a sort of spurious spheroidal structure closely resembling that seen in true perlitcs. I do not think, however, that these, at first sight, similar structures in the two rocks have originated precisely in the same way. They are, nevertheless, deserving of careful comparison, especially when we consider the vitreous nature of the magma in which they are in both instances developed.

* "Transactions of the Royal Microscopical Society," March, 1876.

It is worthy of remark that no crystals of Augite or Plagioclase are visible in this rock; and if we are to regard Tachylite as merely a vitreous condition of basalt, we might infer from magnetite being the only component mineral of basalt which is represented in this rock, that therefore magnetite is the first mineral to crystallize out in the solidification of a basaltic magma. That in some basalts crystals of magnetite are to be seen symmetrically arranged in the planes of accretion of Augite and Olivine crystals seems also to favour such a supposition; but as questions relating to the relative order of development of the component minerals in rocks are fraught with many difficulties and doubts, I am not disposed to express any decided opinion upon the matter until I have examined the subject more attentively, and therefore make my statement rather as a suggestion than as a belief.

In the porphyritic pitchstone of Spechthausen, Nr. Tharandt in Saxony, rod-like bodies may be observed very similar to those which occur in the Slievenalargy Tachylite, coupled with a tendency also to perlitic or minute spheroidal structure.

The Slievenalargy Tachylite presents, as we have now seen, certain structural peculiarities, which ally it to Pitchstone and Perlite; but it exhibits no indications of fluxion texture, shows no streams of microliths, and contains no definitely developed crystals, except those of magnetite. There is no microscopic evidence to support the assumption that it is a vitreous condition of basalt more than of any other rock; so that this assumption, which is doubtless true, must be verified rather by chemical analysis, and by careful observation in the field, of the passages along its surfaces of contact; than by microscopic examination.

Before the blowpipe the rock fuses easily, with intumescence, to a brown or black slaggy glass.

When finely powdered, small particles may be taken up with the magnet.

NOTE ON THE CHEMICAL COMPOSITION OF THE SLIEVENALARGY TACHYLITE.

By the REV. SAMUEL HAUGHTON, M. D.

The following is the chemical analysis of this interesting rock :—

Silica,	.	.	.	.	.	55.40
Alumina,	.	.	.	.	.	13.24
Iron peroxide,	.	.	.	.	.	5.48
Lime,	.	.	.	.	.	7.07
Magnesia,	.	.	.	.	.	1.57
Soda,	2.01
Potash,	1.64
Iron protoxide,	5.64
Manganese protoxide,	0.80
Water,	7.20

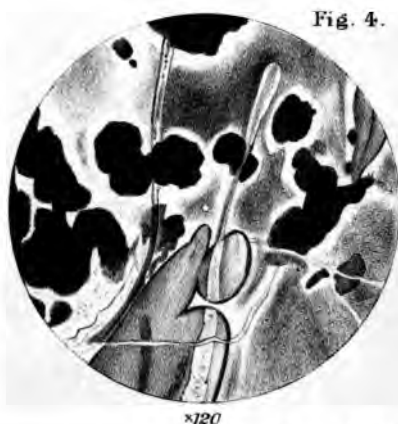
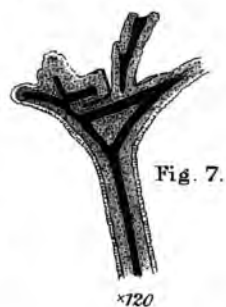
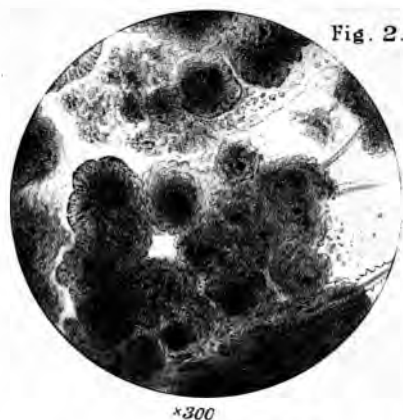
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This rock has nothing in common with Pitchstone, except external appearance; and its large quantity of lime and iron shows it to belong to the Trap Dykes of the Mourne district, described by me in the Journal of this Society, vol. xiv., p. 91 (New Series, vol. iv.) The large quantity of water present shows that it is a Trap Dyke that has undergone metamorphism, to which it probably owes its peculiar appearance.

I would propose to call it *Basaltic Pitchstone*, retaining the term *Trachytic Pitchstone* for the pearly or pitchy rocks of the acid type. The two types of Pitchstone may be distinguished from each other in an instant by the blowpipe.

EXPLANATION OF PLATE.

- Fig. 1. Tachylite of Slievenalargy, County Down, Ireland.—Section magnified 55 diameters, showing rod-like bodies, containing, or fringed with green matter, lacunæ of green matter (ferruginous glass), possibly allied to Glauconite, and dark spots of ferruginous glass: the whole lying in a matrix of glass, in which a very fine dust is visible.
- Fig. 2. Section of portion of the rock seen under a magnifying power of 300 diameters. This is at the margin of the part which appears dark by sub-stage illumination, as shown in Fig. 5. In this drawing the dark patches present a nebulous appearance, are seen to consist of fine dusty greenish matter, and contain some crystals of Magnetite.
- Fig. 3. Section magnified 55 diameters, showing curved rods, and perlitic or spheroidal marking, lacunæ of green glass, vein of yellow glass, and dark segregations of dust.
- Fig. 4. Section magnified 120 diameters, showing segregations of dust and lacunæ of yellow glass, from one of which a rod is extruded. The part of the rod not shown in the drawing appears to terminate within the lacuna.
- Fig. 5. Section of portion of the rock, which appears of a lighter colour than the more glassy parts, when viewed by reflected light; but when looked at by sub-stage illumination presents the aspect shown in the drawing, the dark part being closely-packed segregations of dust, interspersed with little lacunæ of transparent glass.
- Fig. 6. Rod of green glass, constricted near the extremity, and containing crystals arranged along a median line.
- Fig. 7. Diagrammatic drawing of a rod of green glass, with dark core, and cryptocrystalline envelope, branching in such an irregular manner as to indicate that its development did not take place under pressure in any one definite direction.



Frank Rutley del.

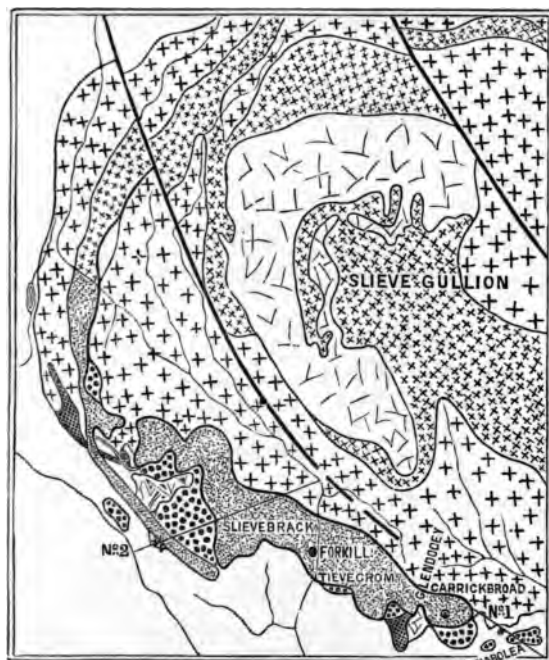
Mintern Bros imp.

TACHYLYTE
from Slievenalargy C^o. Down, Ireland.

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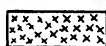
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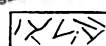
Agglomerate.



Q.F. Porphyry.



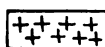
Elvanite.



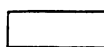
Dolerite.



Diorite (Silurian).



Granite.



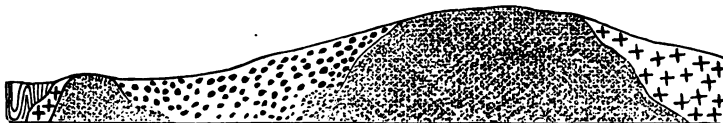
Silurian Slates, &c.

SKETCH MAP OF THE SLIEVE GULLION AND FORKILL DISTRICT.

[Scale—half-an-inch to 1 mile.]



Section No. 1.—Across Slievenabolea.



Section No. 2.—Across Slievebrack.

[Scale—3 inches to 1 mile.]

TO ILLUSTRATE MR. NOLAN'S PAPER ON THE VOLCANIC AGGLOMERATE.

XXXVII.—ON A REMARKABLE VOLCANIC AGGLOMERATE NEAR DUNDALK. By JOSEPH NOLAN, M. R. I. A., of the Geological Survey of Ireland.

[Read, April 11; 1877.]

THE Geological Survey of this district being completed, the following Paper has been drawn up as the result of observations made during the progress of that work, and is published with the consent of the Director-General:—

The theory of the close connexion between the plutonic or hypogene and the volcanic rocks, though for a long time much contested, has now I believe received all but universal acceptance. These two classes can no longer be regarded as essentially distinct, but respectively the lowest or deep-seated and the highest or subaerial members of one continuous system, of which the former, through the effects of denudation, is better exposed for observation in the older rock systems, while the latter, though not without its ancient representatives, is more clearly exemplified in the lavas and other volcanic products of recent times. Occasionally opportunities for a study of the connecting links between these extremes are afforded in the half-ruined volcanic systems of an intermediate period, and in Professor Judd's very excellent Paper on the ancient volcanos of the western islands of Scotland we have an admirable illustration of this kind.* I shall endeavour to demonstrate to you this evening that we have, nearer home, a somewhat similar example, though on a far less magnificent scale, yet possessing a special interest of its own, from the peculiar character of the volcanic products and the extraordinary modification of the phenomena to which they are due. The district I refer to is the hill country north of Dundalk, of which the rugged mass of Slieve Gullion occupies the central and principal portion. This mountain is entirely composed of massive igneous rocks, to which reference will be made in a subsequent part of this essay; the low-lying districts around the base are occupied by a coarse disintegrating granite of Silurian age; while at some distance from and forming a semicircular rampart round the mountain is a chain of low hills, composed of quartziferous felsite porphyry, and on the tops and exterior slopes of these hills is found the remarkable agglomerate which forms the more immediate subject of the present Paper.

Commencing our examination of this district at the south-east, we find in the immediate neighbourhood of the historic pass and castle of Moiry† the low hill of Slievenabolea, composed of Silurian slates,

* "Quart. Journ. Geol. Soc.," vol. xxx., p. 119, part 3.

† Erected by Lord Mountjoy in 1600. The pass of Moiry or Moyra was the scene of frequent conflicts between the Ulster Irish and the soldiers of the Pale.—See D'Alton's "History of Dundalk."

vertical or inclined at high angles, and capped by the agglomerate. The upper portion of this singular rock has here all the appearance of a slate breccia, being mostly made up of pieces of slate similar to that which forms the mass of the hill in a base or matrix of finely comminuted slate fragments. As deeper portions are examined, the almost exclusive slate-breccia character disappears, and fragments of granite, diorite and other local rocks are found, particularly of the quartziferous felstone porphyry of the district, which latter increases in quantity in the lower portions till it ultimately forms the base. Thus, the fragmentary rock passes downward by insensible gradation into a vertical pipe of felstone, which evidently fills up the throat or chimney of a volcanic vent. (See Plate, Section No. 1.)

Between Slievenabolea and the hill of Carrickbroad, which rises to the west, several patches of this agglomerate are found on the slate rocks, and a great mass of it occurs on the south-eastern slope of the latter hill, and also on the summit, where it forms the two remarkable prominences called *Daakilmore*. Here, as at Slievenabolea, the intimate relations between the agglomerate and the underlying porphyry are well shown in vertical sections; the former, however, differs from that at Slievenabolea in containing a larger proportion of granite than of slate fragments. Moreover, it does not seem to mark a volcanic vent, as the entire hill is formed of the porphyry, from which it would appear that these singular rocky hummocks, together with similar patches occurring, as before remarked, near the base of the hill and on the slate rocks, are but small remnants of an immense mass of ejecta, which completely covered up the porphyry, and extended to some distance over the adjacent rocks.

At three-quarters of a mile west of the summit of Carrickbroad, on the south-eastern flanks of the neighbouring hill of Tievecrom, there is a considerable area occupied by this agglomerate, which graduates so insensibly into the porphyry of the hill, both in sections and at the margin, that it is impossible to find any line of demarcation, and an arbitrary boundary had to be drawn on the map. Portions of it also occur near the summit of Tievecrom and other localities in the neighbourhood, but it occupies by far the largest area at Slievebrack, about a mile and a-half north-west of the village of Forkill.

This hill of Slievebrack, like the others just mentioned, is also composed of quartziferous felstone porphyry, and the agglomerate fills up a longitudinal hollow on its south-western flanks. Its most extraordinary character here is, that it consists almost altogether of granite pieces of all sizes, from great blocks to the smallest fragments, in a base of fine granite dust or powder. From the peculiar position it occupies, and its great thickness, the base being in no place visible, it is most probable that this was the chief site or focus of the aëriiform explosions which accompanied the intrusion of the porphyry, and to which this extraordinary mass of disrupted rock is undoubtedly due. (See Plate, Section No. 2.)

The exclusively local origin of the mass will also be evident from the change in its composition; granite fragments prevailing here, where that rock is found *in situ* on both sides of the hill; a mixture of granite and slate at Carrickbroad, near the junction of these formations, and slate fragments almost altogether at Slievenabolea, in the Silurian country to the south-east.

From this description it will be seen that the rock in question differs very much from the usual character of volcanic agglomerates, which consist of scorix and lava fragments, &c., sometimes mixed with a small proportion of the rocks through which the eruption took place, in a base of fine ash or tufa; while here not only the contained block but the base or matrix is made up of fragments of the pre-existing crust. This could not have been the case in an eruption of the usual character, where the igneous mass comes sufficiently near the surface to be discharged in lava or scorix, but was probably due to intense aëriform explosions originating at a greater depth, and extending in a longitudinal direction under a rather large area, producing several cracks and fractures, the rocks between which, thus loosened, were again and again thrown up and reduced by attrition to dust and fragments, forming a vast accumulation or hill of disrupted materials, the immense weight of which, in connexion probably with other causes hereafter to be mentioned, producing a cessation of volcanic power, so that the intumescent igneous mass was not further extruded, but cooled and consolidated beneath. Of this extraordinary modification of volcanic phenomena we have, if not perfectly similar, at least some very analogous examples in recent times, for to some such cause must be attributed the formation of those peculiar crater lakes or *maare* in the Upper Eifel. These are situated on the tops of slate hills, and were undoubtedly produced by explosion, as is evident from the quantities of ejecta that surround them. These latter, however, differ considerably from the tuff or ash thrown out from volcanoes, as they consist chiefly of slate fragments, the *débris* of the strata through which the crater was drilled, mixed up with a small proportion of scorix. "The volcanic energy," says Mr. Scrope, "had been impeded by the mass of transition and secondary strata which it had to pierce, and perhaps by the fragile nature of the greywacke slate, which, shattered and pulverized by the first few aëriform explosions of every eruption, would be likely to accumulate in great volume above and within the vent, and stifle its further activity" ("Volcanoes," p. 384). The resemblance between phenomena of this kind and that at Slievenabolea just described is very suggestive; and if we could examine a section through one of these craters we would doubtless find the slate-breccia graduating downwards into a subterranean lava, just as the similar fragmentary formation at Slievenabolea passes into felstone porphyry.

The igneous rock associated with the agglomerate has been already described as a quartziferous felstone porphyry. Its base varies from

compact to finely crystalline, with orthoclase porphyritically developed, and usually some quartz, which latter mineral generally occurs as double-pyramidal crystals, and often in such quantity as to give the rock a pisolitic appearance.* Petrologically the rock might be called quartz-porphyry; but as that term is usually understood as synonymous with elvanite, which should only be applied to certain hypogene rocks of a granitoid character, I prefer not to employ it in describing a rock associated with volcanic ejecta. It may be regarded as the analogue among the older igneous rocks to the quartz-trachytes or liparites of the present day, to which, indeed, in some parts it bears a close resemblance, particularly like that of Ponza, which appears not to have been ejected at the surface, but to have consolidated beneath an accumulation of agglomerates and other ejected matters. As this mass of quartziferous felstone porphyry is traced to the north, it assumes a granitoid appearance, and mica and hornblende are developed, while the agglomerate thins out and disappears. Still further north this ridge of rock entirely loses its distinctive character, and merges into the great mass of quartzo-felspathic and hornblendic rocks that make up a large portion of Slieve Gullion, and the principal part of the hilly promontory between the bays of Dundalk and Carlingford.† (See Sketch Map, Plate xiv.) This granitoid rock has been already described by many observers, among whom we may mention Mr. Hamilton, Sir Richard Griffith, and Rev. Dr. Haughton, whose valuable Papers on the chemical composition of this and the associated rocks are well known. It may be generally described as a crystalline-granular aggregate of quartz and orthoclase feldspar, with a greater or less admixture of mica or hornblende, particularly of the latter mineral, which is sometimes present in considerable quantity. In this part of the mass the quartz, though it does not crystallize out in the remarkable double-pyramidal form so characteristic of that portion in connexion with the agglomerate, still for the most part occurs as distinct crystals or blebs, while in other places it forms the base or skeleton of the rock; proving that some portions consolidated under much the same conditions as granite, the silica remaining in solution while the other constituents crystallized out.

Associated with these acidic hypogene rocks are others of a basic character. Some of these are hornblendic, consisting of hornblende and plagioclase feldspar; but by far the greater portions are pyroxenic, and exhibit every variety of texture and composition, from coarse hypersthene rocks and micaceous dolerites in what seem to have been the deeper portions, to finer grained dolerites or anamesites, and still

* This remarkable form of quartz was also observed in the Tardree Rhyolite. It is interesting to find so close a resemblance in the form of crystallization of the silica in the Forkill porphyry and a well-known recent volcanic rock.

† For this observation I am indebted to my colleague, Mr. F. W. Egan, B. A., who surveyed the northern portion of the district.

finer augitic rocks, which from their close and compact texture we might almost regard as basalt.* These basic hypogene rocks seem also to have their volcanic representatives accompanied with agglomerates in various detached bosses and tracts among the hills previously described. One of the most remarkable of these is to be seen at Glendooley, where a mass of fine-grained basic rock rises abruptly from the hill side east of the glen. This is certainly an old volcanic vent; the upper portion of the rock is brecciated and agglomeritic, while the base is so closely associated with the tract of melaphyre to the south as to leave little doubt that it proceeded from it.† Another tract, but of larger extent, occurs some miles north of this, but its relations to the surrounding rocks could not be learned; however, still farther north there are other detached masses of basic rocks which graduate at the top into agglomerate. At one of these localities, a little north of Mullaghbane mountain, the associated agglomerate contains a huge mass of Silurian slate. Similar caught-up masses were observed in several places over these hills.

All these basic rocks appear to be of later age than the felstone porphyry, as they have been protruded through it; yet in the Slieve Gullion and Carlingford district the basic rocks seem to be the older, as they are frequently penetrated by dykes and veins from the associated acidic rocks. Possibly these latter have re-melted portions of the old basic rocks, and so given rise to the later pyroxenic eruptions.

Thus it will be seen that the phenomena observed in this district bear a remarkable similarity to that already referred to in the western islands of Scotland. In both localities we have a central mass or core of highly acidic rocks, graduating from those of a granitic type through porphyritic felstone or felsite to compact felstone, associated with others of a basic character, showing gradations from coarsely crystalline gabbros and hypersthénites to dolerite and basalt. The passage from hypogene rocks to those of a volcanic character forcibly reminds us of the late Professor Jukes's observation, that "if we could follow any actual lava stream to its source in the bowels of the earth, we should, in all probability, be able to mark in its course every gradation from cinder or pumice to actual granite" ("Student's Manual of Geology," p. 93). In the typical district of Mull, this almost prophetic announcement receives ample confirmation in the ultimate development of the granitic rocks into contemporaneous lava flows, with their accompany-

* Rev. Dr. Haughton, whose detailed analyses of these rocks will be found in preceding numbers of our Society's "Journal," and elsewhere, shows that the felspar of this hypersthénite is not labradorite but anorthite, which is richer in lime, and is seldom found except in the lavas of Hecla, Vesuvius, and other volcanic districts.

† Professor Hull's microscopic observations prove that the rock consists of plagioclase felspar and epidote, the latter mineral occurring under such circumstances as to suggest the probability of its having replaced augite. See the "Geological Survey Memoir" to accompany sheet 70.

ing scorïæ, ash, and lapilli; while in the Slieve Gullion and Forkill district, though the series is not so complete, we have nevertheless another remarkable illustration in the passage from hypogene rocks to others, which, though not actually volcanic, have by their protrusion produced mechanical accompaniments.

Having now described the igneous rocks associated with the agglomerate and the hypogene roots from which they were derived, it may be well to suggest another cause which may possibly have operated to check the volcanic activity at such a stage as to give rise to the formation of this peculiar mass of ejecta. In one of Professor Judd's admirable Papers recently published in the "Geological Magazine,"* he points out that in the ordinary case of eruptions from an habitual vent, it is probable that the underlying igneous matter occupies a vertical or nearly vertical dyke or throat, so that as pressure is diminished at the surface, and lava or scorïæ ejected, fresh accessions accrue from beneath, the elasticity of the steam, or water imprisoned in the interstices of the lava, causing it to rise, and produce thereby the ordinary phase of continued activity; while if the igneous mass be injected in nearly horizontal sheets or dykes, it will, when it comes sufficiently near the surface to overcome the pressure of the overlying rocks, disrupt the same over a large area, producing a sudden and wide-spread explosion, but of a very temporary character, as there are no deep portions vertically to furnish fresh supplies. Furthermore, according to the views held by Scrope, the coarse porphyritic lavas were, at the time of their intrusion, not in the condition of absolute molecular fusion, but rather granulated magmas with an interstitial fluid, the extreme tension of which is the sole motive power, and which, on being dissipated by explosion, leaves a solidified mass behind. Applying these considerations to the present case, we find that the Forkill porphyry occurs as a dyke-like protrusion from the great mass of granitoid rocks of the district, though in itself it is of no inconsiderable extent; so that the aëri-form discharges were continued for some time, portions of the shattered crust being, as before remarked, thrown up again and again, and rounded and pulverized by attrition; but owing partly to the circumstances just mentioned, as well as to that before pointed out, viz., the immense weight and quantity of displaced materials, the volcanic energy was exhausted before the igneous matter could be developed into lava or scorïæ.

Of the age of these rocks we have little evidence, except that they are post-carboniferous, the limestone in contact being altered. They may be referred with much probability to that great period of volcanic activity which is believed to have taken place about the close of the Palæozoic epoch, as the physical changes that have since taken place are so vast. The western parts of the Slieve Gullion district seem to have been affected by a number of N. W. and S. E. faults, with down-

* Vol. ii., No. viii., August 1875.

throws to the west, of considerable extent, so that the great covering of Silurian granite, and other formations under which the hypogene rocks of the district must have been formed, were removed, and the latter now form the highest mountains, while the portions that, from clear evidence, originally formed the surface, are now found at a much lower elevation. This will be evident from a glance at the accompanying sketch map. *

Professor Hull is of opinion that the neighbouring granite of Mourne is contemporaneous with these rocks, a supposition which seems extremely probable. In the Geological Survey Map of that district,* the granite is represented as passing in the marginal portions into elvanite, a circumstance which offers a fair presumption of its connexion with the same class of rocks in the district just described.

XXXVIII.—ON A TRIPLE SYSTEM OF POST-MIOCENE FAULTS IN THE BASALTIC REGION AROUND LOUGH NEAGH. By EDWARD T. HARDMAN, F.C.S.

[Read, April 11, 1877.]

IN the basaltic district around Lough Neagh there are very numerous faults, with regard to which the following points may be considered worthy of notice:—

There appear to be at least three distinct sets of faults, of different dates—but belonging to the post-miocene age—each of which preserves its own distinctive bearing. The general direction of them is as follows:—

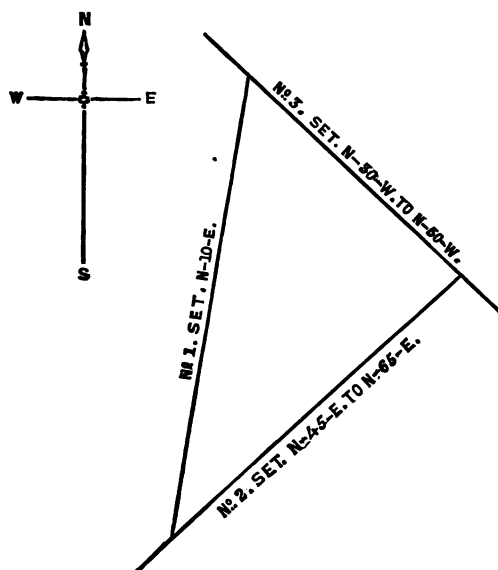
No. 1,	N. 10 E.
No. 2,	N. 45 E. to N. 65 E.
No. 3,	N. 30 W. to N. 50 W.

No. 1. The oldest of these runs about N. 10 E. The principal fault of this set occurs at Crew Hill, a little west of the town of Stewartstown, where it brings down the basalt against the Carboniferous limestone, the downthrow being apparently very considerable. This fault proves to be the key to the whole series, for both north and south it is cut off by two faults belonging to the next set. These, it could be easily shown from the position of the basalt at Crew Hill with reference to that of the main body of that rock, are of later date. Several minor faults parallel to the first-mentioned fault have been observed. They appear to be of the same date.

No. 2. This set may be said to have a general north-easterly direction: the variation ranging from N. 45 E. to N. 65 E. It is an ex-

* Sheets 60 and 61. Surveyed by W. A. Traill, M.A. I.

tremely well marked and important one, the individual members having very large downthrows indeed. Of these, the principal are the great boundary fault of the Dungannon coal-field, which has a total downthrow of at least 2000 feet, part of which may, however, be due to pre-miocene subsidences along the same line of fracture. This fault I consider to cross Lough Neagh, and have its continuation in the great Templepatrick fault, which, according to Professor Hull, has a downthrow to south-east of from 400 to 500 feet.* North of this fault, and parallel to it, is the Annaghone coal-field fault, bringing down the Bunter sandstone against the Coal-measures in one place, and the basalt



against the Trias in another. A boring on the south of it, close to the coal-field, is said to have gone through 300 feet of Triassic rock. On the whole, this fault may probably have a downthrow to the south of 1000 feet. Still further north, two faults with downthrows north and south respectively, of about 200 feet, run in the same direction, and in the neighbourhood of Moneymore faults of smaller magnitude, but with the same general bearing, cut into the basalt escarpment.

Several faults of various degrees of magnitude belonging to this system occur along the escarpment running south-west from Cave Hill to near Moira.

* Ex. Mem. Sheets 21, 28, 29, Geol. Survey, Ireland, p. 37.

No. 3. The third and apparently latest set has a general N.W. or N.N.W. bearing, varying from N. 30 W. to N. 50 W. This set invariably cuts through No. 2, as may be noticed in many places in the vicinity of the Dungannon coal-field, the boundary fault of which is cut by two of them. In the case of the numerous small faults which cut into the basalt escarpments on all sides of the district, it appears to be invariably the case that this set of faults dislocates the others. This may be seen on the published maps of the Geological Survey, on which very few exceptional instances will be observed.

The downthrow of this set of faults is apparently always comparatively small, the greatest I have any information of being 54 feet. It occurs in the Dungannon coal-field. This agrees well with its being of latish date, when the subsidences over the volcanic area were coming to a close.

It may perhaps be pointed out that the general bearing of this set of faults coincides very fairly with that of a great number—if not a majority—of the basaltic dykes which traverse the basalt of the north of Ireland. It might be that the forces which gave rise to these latest lines of fracture helped to produce those fissures into which the intrusive basalt was not so much ejected as admitted—that is, that the fissured basalt, at this last subsidence, may have settled down into the molten magma below, in such a manner that the fluid lava was forced into the fissures.

It would be hasty to draw conclusions as to the probable concordance of the post-miocene fault systems of other districts in the north of Ireland with those of the part under notice; and the chief object of this imperfect note is to draw the attention of other observers to such a possibility. But I may mention that Professor Hull describes two distinct systems of faults as dislocating the basalt to the north-east; * in the district comprising Larne, Island Magee, Templepatrick, &c. The systems he refers to are :—a *south-westerly* system, corresponding to No. 2 above, the principal fault of which, at Templepatrick, I have alluded to; and a *N.-N.-westerly* system, corresponding to what I have described as No. 3. It does not appear, however, that the relative ages of those two sets of faults have been ascertained.

It must be borne in mind that in stating the bearings of the different sets of faults I mean the average direction of the whole fault.

* Ex. Mem. Sheets 21, 28, 29, Geol. Survey, Ireland, pp. 36–37.

XXXIX.—ON THE OCCURRENCE OF PHOLADIDEA PAPYRACEA AT GLENARM, COUNTY ANTRIM. [With Specimens.] By W. A. TRAILL, M.A.I., H.M. Geological Survey, Ireland.

[Read, May 9, 1877.]

IN bringing this short Paper before your Society, on the occurrence of Pholadidæ at Glenarm, I thought that it might be of interest to exhibit some of the specimens which I found, and to record this additional locality, where these rare shells are met with.

My friend the Rev. J. Grainger, D.D., who has particularly studied recent shells in connexion with his researches into our post-tertiary deposits, has kindly named them for me, and has rendered me other assistance concerning them. I have compared them with Forbes' and Hanley's illustrations, with which they mostly agree.

Of the particular family of Mollusca to which I refer, viz., to the boring shells, the Pholadidæ, the three commoner species—*Pholas candida*, *Pholas crispata*, and *Pholas dactylus*—are found without very great difficulty, at low tides, along the shores of Belfast Lough.

But during the last winter I was fortunate enough to find a number of specimens of the rarer species—*Pholadidea papyracea*—on the shore between Glenarm and Carnlough.

It was after some storms that I obtained them, and a great number of the animals were alive, showing that they were now existing in that locality. They may have been thrown up from deep water outside, or they may exist immediately along the shore, at or below low-tide level.

The marls of the New Red Sandstone seem to be the rock which they peculiarly inhabit, and into which they bore. In some cases a small block of this rock, 3 or 4 inches in diameter, would be completely honeycombed by a dozen or more of these shells.

They mostly entered by small holes from the outside, growing in size as they excavated and advanced, till they became permanently inclosed in their self-formed prisons. The entrances to some of these would be less than $\frac{1}{4}$ inch across, while inside some had attained to over $\frac{3}{4}$ inch in diameter.

The peculiar markings on the insides of the holes, formed by the workings of the muscular foot, with which they made their excavations, were often clearly visible.

The more abundant forms were those of the full-grown *Pholadidea papyracea*. The shells are of an elongated ovate shape, very thin and fragile; an oblique line forms a depression on the outside, and a rib internally. The hinder parts are marked with broad concentric wrinkles, and are provided with cup-like appendages, sometimes $\frac{1}{2}$ inch beyond the extremity of the shell; these are composed of papyraceous or paper-like vaulted laminæ.

The anterior parts of the shells are again divided, the portions

near the beak being closely and obliquely marked with linear platings, but the remaining portion is smooth and rounded, filling up the front ventral opening with an excessively thin and fragile shelly matter; these are connected across by a membrane.

On the insides of the shells are two hooks, one in each valve, upon which the animal seemed to hang up its body, as well as to be attached to the shells by muscles.

The largest specimen obtained was a little over $1\frac{1}{2}$ inch in length.

Another and rarer form was that which was unprovided with the calyx, or cup-shaped appendage, at the posterior end, it being rounded off and attenuated; this form also wanted the dome-like structure at the anterior extremity, which consequently gaped, and was connected directly across by a membrane.

This variety has caused much controversy among British conchologists, and by some is considered the young or undeveloped state of the *Pholadidea papyracea*; but by Dr. Turton and others was considered a different species, and to it was given the name of *Pholas lamellata*,* supposing it not the young of the papyracea. That it was "in fact a kind of monstrosity, or at least a specimen of an unusual growth, and extremely rare; that the animal, instead of attempting to inclose the front ventral group with testaceous matter, upon the completion of the immature stage of growth, had contented itself with solidifying the entire shell, and reflecting the edge of its anterior ventral margin."

The following extract is communicated by Mr. Jeffreys from the manuscripts of Mr. Clark (*vide* Forbes' and Hanley's *British Mollusca*):—

"This animal, in consequence of the shell having been taken under very different appearances of form, has . . . been considered a distinct species, and named by Dr. Turton the *Pholas lamellata*. . . . But having studied the animal under both forms, we are fully enabled to confirm Mr. Sowerby's opinion that the two shells are one species under different forms. We do not, however, think that the form styled *P. lamellata* is the young of the shell styled *P. papyracea*, but that they each maintained their form when of all sizes, from circumstances depending on peculiarities of animal economy. In corroboration of this opinion, we have seen *P. lamellata* equal in size to the largest *P. papyracea* and *P. lamellata* completely formed, with the cup and testaceous membrane, not more than $\frac{1}{4}$ inch in length."

This I can corroborate, as some of the smallest specimens had the calyx complete, and the largest one that I found was of the form *P. lamellata*, and was nearly $\frac{1}{2}$ inch in diameter. Both forms were often found in the same stone.

The above extract further states:—"We believe that when pe-

* *Pholas constricta*.

culiar circumstances, most probably attendant on habitat or animal economy, arose, the animal has then the power of forming the cup and membrane. The cup we consider as nothing more than the incipient shelly lining of its habitation, for the protection of some part of its tubes.

"Few specimens attain to a greater dimension than $1\frac{1}{2}$ inch, and about half that breadth."

With regard to the localities where these shells are found, Forbes and Hanley state that the *Pholas papyracea* must be considered not only a very local shell, but one difficult to procure, even at most of the spots from whence it can be obtained. It is met with at low tides at Exmouth, Tynemouth, Torquay, and other South Devon towns; and they also state that it was dredged up between Howth and Lambay.

In the "Guide to Belfast," published by the Belfast Naturalists' Field Club for the meeting of the British Association in 1874, I find in the list of bivalve Mollusca that the *P. papyracea* was found at Portrush, and in deep water off The Maidens, two islands near Larne. Dr. Grainger, who dredged them, informs me that they were but small specimens. He also found some others at Whitehead.

No mention is, however, made of the variety or species *P. lamellata* having been previously found in those districts.

In "The Guide" for the British Association meeting at Glasgow in 1876, in the list of Mollusca, only the *Pholas crispata* and *dactylus* species are enumerated, and no mention is made of the *P. papyracea* having been obtained.

With regard to the county Antrim coast, and the occurrence of this family of boring shells, viz., *Pholadidea*, from the fact of their favourite rock, the New Red Sandstone, occurring continuously or at intervals along the coast, and specimens of one or other species being found, as *P. candida*, *P. crispata*, and *P. dactylus*, at Belfast Lough, and *P. papyracea* at Whitehead, The Maidens, Glenarm, and Carnlough, and at Portrush, we may, I think, reasonably conclude that there at present exists a belt or zone of representatives of this family, in deep water or at low-tide level, along a considerable portion of the county Antrim coast line, and that it only requires more attentive search or dredging in that zone to procure many other specimens.

In the discussion which followed, Dr. Haughton stated that Dr. Farren had also found the *Pholadidæ* along the coast of Waterford, comprising the *P. papyracea*, in some pieces of wood, or in fact in a submerged peat bog.

XL.—ON THE NATURE AND ORIGIN OF THE BEDS OF CHERT IN THE UPPER CARBONIFEROUS LIMESTONES OF IRELAND. By Professor EDWARD HULL, M.A., F.R.S., Director of the Geological Survey of Ireland. With CHEMICAL NOTES, by E. T. HARDMAN, F.C.S., of the Geological Survey of Ireland.

[Read, May 9, 1877.]

(ABSTRACT.)

AFTER reviewing what had been published by previous authors on the origin of chert-beds, and showing that much remained to be done in this department of petrology, the author proceeded to describe the geological position of the principal cherty zone of the Carboniferous limestone of Ireland, showing that, while bands of chert occur at intervals throughout this formation, the highest beds immediately under "The Yoredale Shales" are especially rich in chert, and are frequently entirely replaced by this mineral. In these beds coralline, crinoidal, and other marine forms were frequently to be recognised by the naked eye. Thin slices for microscopic examination, taken from various localities, extending from Sligo to Carlow, also showed that even the most dense and compact masses of chert exhibit, under favourable circumstances, forms belonging to those of marine animals (such as corals, crinoids, foraminifera, and occasionally molluscs), which build their shells or skeletons of carbonate of lime rather than of silica. The siliceous paste in which these forms are inclosed was found to have been in a "gelatinous state," and the forms were only to be distinguished by difference in depth of shade from the paste, the shells or skeletons having disappeared. The chemical analyses of these specimens by Mr. E. T. Hardman, F.C.S., tended to show that the chert-beds contain various proportions of carbonate of lime as well as of other minerals, so that a gradation from siliceous limestone into pure chert might be traced.

From a review of the whole circumstances, it appeared that the origin of the chert-beds was to be attributed to the replacement of the original limestone or calcareous "ooze," due to organic agency, by silica, and that the rock is truly a pseudomorph;—a view held by several observers.

The manner in which this replacement has been brought about was then touched upon. It was shown that there was reason for believing that at the close of the period during which the Carboniferous limestone was formed over the area of central Ireland, the sea-bed was elevated, so as to be covered by the waters of a shallow sea, exposed to the sun's rays, and of a warmer temperature than when at a greater depth. The waters appear to have been charged with a more than usual supply of silica in solution, derived (as Mr. Hardman suggests) from the surrounding lands, formed, for the most part, of highly siliceous materials. As silica is less soluble than carbonate of lime, chemical replacement would naturally take place, the carbonate of

lime being dissolved out, and its place taken by the silica. The warm condition of the sea-water, its exposure to sunlight, the porous character of the coralline, crinoidal, and other forms, and the soft and "oozy" condition of the foraminiferal mud, would give easy access to the sea-waters, and the process of silicification would take place, analogous to that described by Dr. Martin Duncan, F.R.S., as having occurred in the West Indies.

The Paper was accompanied by chemical analyses and photographic figures of some of the thin slices, slightly magnified.

XLI.—OBSERVATIONS ON THE REMAINS OF MAMMALS FOUND IN A FOSSIL STATE IN IRELAND. By A. LEITH ADAMS, F.R.S., F.G.S., Professor of Zoology in the Royal College of Science, Dublin.

[Read, May 9, 1877.]

I AM induced to lay before the Society a few observations on the fossil mammals of Ireland, in consequence of my own conclusions with reference to certain specimens being not in agreement with the determinations of previous writers.

The latest published lists, such as those of Mr. Scott, F.R.S.,* and Professor Hull, F.R.S.† (copied more or less from Catalogues and Papers in the "Journal of the Geological Society of Dublin," and "Journal of the Royal Dublin Society"), I find no less than four species of the genus *Ursus* enumerated—to wit, *Ursus arctos*, *Ursus spelæus*, *Ursus maritimus*, and *Ursus ferox*. The specimens from which these species were differentiated are, for the most part, in good states of preservation, and readily accessible.

1. With reference to *Ursus arctos*, as determined from a cranium found in the county of Kildare, and certain bones from Shandon Cave, it appears to me that the skull is the only one of these specimens admitting of accurate comparisons with recent or extinct bears. It is probably that of a young female, with the ridges not well developed, and is therefore also unsatisfactory for comparative purposes. Its black colour might indicate a bog origin, of which however there is no clear evidence. It is smaller than the five other Irish crania, which not only in the histories of their discoveries, but also in general aspects, show that they were found either, as in the case of Shandon Cave, in a calcareous deposit, or as in the other four, in sub-turbary formations. The Kildare skull shows, in its dental characters, and in the contour of the posterior nasal openings, affinities more in accord with the same parts in *Ursus spelæus* and *Ursus ferox*. I am, therefore, disposed to consider it as merely an immature individual of either of these forms, now admitted by many comparative anatomists to be one species.

* "Journ. Geol. Soc., Dublin," vol. x. p. 143, and "Geol. Mag." vol. vii. p. 413.

† Presidential Address, "Journal of Royal Geological Soc. of Ireland," vol. iv. (n.s.), p. 51.

2. The ursine bones, from Loch Gur, described by Dr. Carte, F.L.S.,* and considered by him as belonging to *Ursus maritimus*, have engaged my particular attention, from the importance of such a rare, I may say unique, discovery. After careful examinations and comparisons of these remains with the same parts of the recent animal, and not only with specimens in the Museum of the Royal Dublin Society, but the rich collections in the Hunterian Museum, London, I have failed to perceive the resemblances he has recorded as existing between the Loch Gur bones and those of the recent Polar bear. Indeed, on the contrary, I find that, whilst the long bones from Loch Gur and Shandon Cave agree, as they do also with the same parts in *Ursus spelæus* and *Ursus ferox*, and even *Ursus arctos*, inasmuch as all four show very unimportant distinctions in their long bones, there are pronounced differences between them and the same parts of *Ursus maritimus*; in fact, *Ursus maritimus* is very different in its osteology from other recent and from hitherto found fossil species.

I moreover regard *all ursine remains*, hitherto recorded, from Irish deposits as belonging to one species, and undistinguishable from the same parts of the *Ursus spelæus*, whose osteology agrees so closely with the grisly bear (*Ursus ferox*) that many authorities consider them to be one and the same species. It may be observed that there is no historical account of the brown bear having been a native of Ireland, as was the case in Scotland and England, whilst both islands agree so far that there is no written record of the *Ursus spelæus* having been contemporary with man.

The authenticated remains of the Mammoth, as far as I can make out, are confined to the discoveries in Cavan and Waterford. I have lately seen a photograph of a portion of a molar of this species, which I am informed by the Rev. Dr. Grainger, of Broughshane,† was discovered by him in a marine deposit on the sea shore of the county of Antrim.

The presence of the Hippopotamus in Ireland rests on a canine tooth said to have been discovered in the county of Antrim, a drawing of which tooth is preserved in the Office of the Geological Survey of Ireland.‡

Although the Pig was feral in Ireland during the early historical times, I can find no evidence of its remains having been met with in a fossil state, or associated with any of the extinct mammals.

* "Jour. Geol. Soc. Dublin," vol. x., p. 115.

† Dr. Grainger refers in a Paper read at the Belfast Meeting of the British Association, 1874, to other discoveries of Mammoth remains, but he considers that none except the above have been authenticated. The molar said to have been found in the Cave of Dunmore, county Kilkenny, and lately exhibited by the Rev. Dr. Haughton, T. C. D., at a meeting of this Society, appears to me to belong to the recent Asiatic elephant.

‡ Dr. Moore makes a mistake in his letter to Professor Hull, quoted by the latter in his Presidential Address, delivered before this Society in 1876, in stating that the tooth belonged to an *elephant* [see vol. iv. (n.s.), p. 51].

Neither *Bos longifrons* nor *Bos frontosus*, now admitted by many authorities as only varieties of domesticated oxen, are found in any deposits of Irish Pleistocene age.

The Moose (*Cervus alces*) has been included in several Irish lists, but it appears to me on no valid authority. The horn said to have been found in Ireland, and now in the Museum of Belfast, is clearly an importation, and belongs to a recent individual. The Ovine and Caprine remains, met with in cavern and other deposits, are evidently of domesticated individuals.

The Cetacean remains I am unable to confirm from personal observation; nor is there any evidence of their fossil exuviae that I can discover, the specimens being apparently from superficial deposits.

From a study of the foregoing and other remains, described in detail in a Monograph on Irish Fossil Mammals which I have forwarded to the Royal Irish Academy, it appears to me that the only mammals hitherto met with in a fossil state in Ireland are as follows:—

Equus caballus.
Cervus megaceros.
Cervus tarandus.
Cervus elaphus.
Elephas primigenius.
Hippopotamus (?).
Canis lupus.
Canis vulpes.
Ursus spelæus (*Ursus ferox fossilis*).
Lepus variabilis.

With the exception of the Irish elk and hippopotamus, all these mammals were found in the same deposits, and their remains intimately associated, so as to lead towards the belief that they were contemporaneous. The reindeer, red deer, and Irish elk have also been found in the same subterranean deposits, and their remains in close proximity.

The above catalogue will be found exceedingly meagre, as regards both genera and species, in comparison with lists of the Pleistocene mammals of England, and might indicate either that the climate and physical characters were inimical to such animals, or else that an early separation of Ireland from England took place, giving time for only the hardier and more vagrant animals to push westwards. The presence of only the wolf and bear as representatives of the larger carnivora, and absence of the lions, hyænas, and such like, may account for the abundance of the remains of the Irish elk. I admit, however, that this inference is still premature: indeed had it not been for the valuable discoveries made by the late Mr. Brennan in Shandon Cave, the list of Irish fossil mammals would have been even less numerous than above, and without the contemporaneity of the species which that rock cavity revealed. But they have done more, for they show that the Irish limestone caves should be carefully explored.

XLII.—ON THE COMPOSITION OF THE BUXTON LIMESTONE, AND ON THE LIMES SUITABLE FOR THE MANUFACTURE OF BLEACHING POWDER. By R. LAURENCE, Associate, and C. CLARKE HUTCHINSON, Royal Exhibitioner, Royal College of Science, Dublin.

[Read, June 13, 1877.]

THE fact of the Buxton limestone being so largely used for the manufacture of bleaching powder, and the superiority of the product obtained from it over that from other sources, suggested that a knowledge of its composition would be interesting and useful, as a standard of comparison for the adaptability of other limestones for a like purpose. Although in most scientific and technical works on chemistry the repute of this limestone is mentioned on treating of bleaching powder, yet in none of these works with which we are acquainted is there any information given of its composition; nor are we aware that any complete analysis of it has been hitherto published.

The result of this analysis, as compared with some of our Irish limestones, might also show that they might be utilised with material advantage for the manufacture of these important commercial products. The samples analysed were furnished by Professor Galloway, who had personally selected them from the quarries worked in the vicinity of Buxton. The investigations were carried out in the Chemical Laboratories of the Royal College of Science, and under his supervision.

The appearance of the stone is of a greyish-white colour, crystalline, and very compact, containing small, shining crystals of carbonate of lime, with irregular occurrence of siliceous matter. It is of notable hardness and great density, and the fractures (which are generally smooth, and often of a conchoidal nature) bring to light the fossiliferous character of the rock.

Two sets of independent analyses were carried on by us, the subjoined being the respective means of the results so obtained.

Having proved by a careful qualitative analysis, conducted in the usual manner, the presence of the following constituents, in addition to the carbonate of lime—organic matter, silica, iron, magnesia, potash, and soda, traces of alumina, phosphoric acid, together with very faint traces of hydrochloric and sulphuric acids, the separation and estimation of these bodies were proceeded with in the following way:

After carefully sampling and reducing the specimens to powder, about six grammes of the substance were taken for each analysis, and treated with hydrochloric acid. . . . The acid solution was evaporated to dryness on the water bath, the residue was moistened with a small quantity of hydrochloric acid, and a tolerably large quantity of water added. The solution was then warmed, and filtered through a tarred filter, dried at 100° C. . . . The insoluble residue (which consisted of sand, silica, and organic matter) was washed, dried at 100° C., and weighed; this gave the weight of the total insoluble matter.

The filter and insoluble matter were then ignited in a tarred cru-

cible and weighed; this gave, after deducting the filter ash, the quantity of sand and silica; and the difference in weight between the total amount of insoluble matter and the silica and sand, the amount of organic matter. The insoluble inorganic matter, being so slight, was not further examined.

To the filtrate from above, chlorine water was added to peroxidise the iron; the solution was then warmed, and ammonia added in slight excess. After being allowed to stand for some time in a covered vessel, it was filtered into a litre-measuring flask; the precipitate was again dissolved in hydrochloric acid, chlorine water and ammonia again added, the solution allowed to stand, and then filtered through the same filter as before—the filtrate being collected in the same flask; this precaution was taken to insure the complete separation of the lime from the iron, &c. (some small portion being liable to precipitation as carbonate during filtration from the carbonic acid in the air). . . . The precipitate was then dried, ignited, and weighed; this gave the amount of iron, with the traces of alumina and phosphates, which being very small were not further separated.

The litre flask, in which the ammonia solution and wash-water had been collected, was then made up to the mark.

Two estimations of lime were made in each analysis, 200 cc.s of the solution being employed in each case; the lime was precipitated by ammonia and oxalate of ammonia, and estimated as carbonate in the usual way.

The filtrates and wash-waters from each of these portions were then added together, evaporated to dryness, and gently ignited, to expel the ammonia salts, when cold water and hydrochloric acid were added to the residue, and the solution treated with ammonia and phosphate of soda in excess; after standing twelve hours, the precipitate of phosphate of magnesia and ammonia was filtered off, dried, and after ignition weighed, as pyrophosphate of magnesia ($Mg_2P_2O_7$); and from this the weight as magnesia (MgO) was calculated.

For the estimation of the alkalies, a separate portion of 200 cc.s of the ammonia solution was taken from the litre flask. The lime from this was precipitated by oxalate of ammonia, and after filtration the solution was evaporated to dryness with a small quantity of pure oxalic acid, this being added to ensure the conversion of the whole of the bases into oxalates; on ignition, the magnesian and alkaline oxalates were converted into carbonates, the alkaline carbonates being then separated by treatment with a very small quantity of water. Hydrochloric acid was added, the solution evaporated to dryness, and weighed in a tarred platinum dish; this gave the amount of mixed chlorides. A small quantity of water was now added, and to this solution an excess of bichloride of platinum; after evaporation nearly to dryness, the residue was treated with alcohol of 0.86 specific gravity, and allowed to stand; the precipitate was afterwards filtered off through a small tarred filter, washed with alcohol, and weighed as the double chloride of potassium and platinum; from this was calculated

the weight of potassic chloride present, which, deducted from the weight of the mixed chlorides, gave the weight of the sodic chloride both of which were then calculated to their respective oxides.

The carbonic acid was estimated with the aid of a modification of Will's and Fresenius' apparatus.

The following Table represents the percentage composition of the limestone, as obtained by us :

<i>Substances.</i>	I.	II.	Mean.
Silica and Silicates,	0·884	0·923	0·903
Organic Matter,	0·017	0·029	0·023
Oxides of Iron, Alumina, } and Phosphates, }	0·265	0·219	0·242
Lime (CaO),	54·752	55·064	54·908
Magnesia (MgO),	0·314	0·555	0·434
Potash (K ₂ O),	0·254	0·126	0·190
Soda (Na ₂ O),	0·242	0·614	0·428
Carbonic Acid (CO ₂),	43·783	43·196	43·489
Hydrochloric and Sulphuric acids, }	Traces.	Traces.	—
Totals,	100·511	100·726	100·617

Specific Gravities.

I. Taken in the mass,	2·76
II. Taken by bottle as powder,	2·7
III. Portion insoluble in HCl. taken by bottle,	3·5

As regards the suitability of limestones for their conversion into bleaching powder, we will quote the following from a recently published work, "Chemistry, as Applied to the Arts and Manufactures," page 477 :—

"The limestone for this purpose should be as free as possible from iron and manganese, because they impart to the bleaching powder a dark colour. The presence of considerable quantities of magnesia is said to be disadvantageous, inasmuch as the chloride of magnesium, which forms in the treatment with chlorine, absorbs water from the atmosphere with much more avidity than the corresponding lime compound, and the magnesium hypochlorite, which too is formed under the influence of the chlorine, decomposes very readily; two properties which easily lead to the spoiling of the bleaching compound. This statement is, however, contradicted by experienced manufacturers. . . . Two kinds of limestone are generally used, one called 'clipp,' which is brought from France; the other a pure limestone from Buxton."

This seems entirely to agree with the results we have obtained; for it will be seen that the substances which are here mentioned as dele-

terious to the chlorinated product are either absent, or present only in extremely small quantities, the carbonate of lime forming the great bulk of the stone.

As regards the presence of magnesia, many authorities have stated, contrary to the above, that the presence of a certain amount of magnesia is beneficial, but our analysis disagrees entirely with this statement, it being perceived that the quantity of magnesia present is inappreciable in its amount.

Two other advantages accruing from the use of this limestone are, 1st, that the powder made from it retains its chlorine, and is therefore highly suitable for transmission and storage; 2nd, that in making the bleaching solution from it the insoluble matter settles down (leaving a clear solution) very rapidly. This latter property would evidently be expected, for, on reference to the specific gravities given above, it will be seen that the insoluble matter is of a very much greater density than the bulk of the limestone.

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APPENDIX.

No. I.

LIST OF FELLOWS CORRECTED TO DECEMBER 31, 1873.

Fellows are requested to correct errors in this List, by letter to the Hon. Secretaries, 35, Trinity College, Dublin; or to the Assistant Secretary.

OFFICERS OF THE SOCIETY FOR THE YEAR 1873.

PRESIDENT.—Edward Hull, M.A., F.R.S.

VICE-PRESIDENTS.—Earl of Enniskillen; Colonel Meadows Taylor, M.R.I.A.; Rev. S. Haughton, M.D., F.R.S.; Rev. H. Lloyd, Provost, T.C.D.; Sir Richard Griffith, Bart., LL.D.

TREASURERS.—William Andrews, Esq.; Samuel Downing, LL.D.

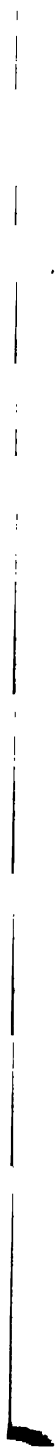
SECRETARIES.—J. Emerson Reynolds, F.C.S.; Alexander Macalister, M.B.

COUNCIL.—Sir R. Kane, F.R.S.; Alphonse Gages, M.R.I.A.; B. B. Stoney, C.E.; William Frazer, M.D.; Alexander Carte, M.D.; W. H. S. Westropp, M.R.I.A.; C. R. C. Tichborne, Esq.; Rev. Maxwell Close, M.A.; Francis M. Jennings, F.C.S.; John Ball Greene, Esq.; William H. Baily, F.G.S.; J. McCarthy Meadows, C.E.; Hugh Leonard, M.R.I.A.; Edward Hardman, F.G.S.; R. G. Symes, F.G.S.

HONORARY FELLOWS.

Elected.

- | | |
|-------|--|
| 1844. | 1. Boué, M. Ami, For. Mem. L.G.S., M.D., <i>Académie Imp. Sc., Vienna.</i> |
| 1865. | 2. Burton, Captain R. F., H.M. Consul, <i>Santos.</i> |
| 1861. | 3. Daubrée, M., Membre d l'Institut, 91, <i>Rue de Gréville, St. Germain, Paris,</i> |
| 1861. | 4. Delesse, M., Ingénieur des Mines, <i>Paris.</i> |
| 1865. | 5. Des Cloiseaux, M., Prof. of Mineralogy, <i>Jardin des Plantes, Paris.</i> |
| 1861. | 6. De Serres, M. Marcel, <i>Montpelier.</i> |
| 1861. | 7. Deville, M. C. Ste.-Claire, <i>Paris.</i> |
| 1861. | 8. Deville, M. H. Ste.-Claire, <i>Paris.</i> |
| 1861. | 9. De Koninck, M. L., For. Mem. L.G.S., <i>Liège.</i> |
| 1861. | 10. Geinitz, M. H. B., For. Mem. L.G.S., <i>Dresden.</i> |
| 1863. | 11. Hunt, Dr. T. Sterry, F.R.S., <i>Montreal.</i> |
| 1844. | 12. Lyell, Sir Charles, F.L.S., 73, <i>Harley-street, London, W.</i> |
| 1861. | 13. M'Clistock, Sir Leopold, R.N., 21, <i>Merrion-square, North.</i> |



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HONORARY FELLOWS.

Elected.

- | | |
|-------|--|
| 1844. | 1. Boué, M. Ami, For. Mem. L.G.S., M.D., <i>Académie Imp. Sc., Vienna.</i> |
| 1865. | 2. Burton, Captain R. F., H.M. Consul, <i>Santos.</i> |
| 1861. | 3. Daubrée, M., Membre d l'Institut, 91, <i>Rue de Gréville, St. Germain, Paris,</i> |
| 1861. | 4. Delesse, M., Ingénieur des Mines, <i>Paris.</i> |
| 1865. | 5. Des Cloiseaux, M., Prof. of Mineralogy, <i>Jardin des Plantes, Paris.</i> |
| 1861. | 6. De Serres, M. Marcel, <i>Montpellier.</i> |
| 1861. | 7. Deville, M. C. Ste.-Claire, <i>Paris.</i> |
| 1861. | 8. Deville, M. H. Ste.-Claire, <i>Paris.</i> |
| 1861. | 9. De Koninck, M. L., For. Mem. L.G.S., <i>Liège.</i> |
| 1861. | 10. Geinitz, M. H. B., For. Mem. L.G.S., <i>Dresden.</i> |
| 1863. | 11. Hunt, Dr. T. Sterry, F.R.S., <i>Montreal.</i> |
| 1844. | 12. Lyell, Sir Charles, F.L.S., 73, <i>Harley-street, London, W.</i> |
| 1861. | 13. M'Clintock, Sir Leopold, R.N., 21, <i>Merriion-square, North.</i> |

HONORARY CORRESPONDING FELLOWS.

Elected.

- 1859. 1. Gordon, John, C.E., *India*.
- 1859. 2. Hargrave, Henry J. B., C.E., *India*.
- 1859. 3. Hime, John, C.E., *Ceylon*.
- 1858. 4. Kingsmill, Thomas W., *Hong Kong*.
- 1855. 5. Medicott, Joseph, *India*.
- 1854. 6. Oldham, Thomas, F.R.S., *Calcutta*.

FELLOWS WHO HAVE PAID LIFE COMPOSITION.

- 1853. 1. Allen, Richard Purdy.
- 1861. 2. Armstrong, Andrew, 16, *D'Olier-street*.
- 1857. 3. Carson, Rev. Joseph, D.D., S.F.T.C.D., *Trinity College*.
- 1857. 4. Dowse, Rt. Hon. Baron, *Mountjoy-square*.
- 1872. 5. Durham, J. S. W., *Glasthule House, Kingstown*.
- 1861. 6. Fottrell, Edward, *Fleet-street*.
- 1862. 7. Frazer, W., M.D., M.R.I.A., 20, *Harcourt-street*.
- 1857. 8. Greene, John Ball, 6, *Ely-place*.
- 1848. 9. Houghton, Rev. Professor, M.D., F.R.S., 40, *Trinity College*.
- 1862. 10. Henry, F. H., *Lodge Park, Straffan, Co. Kildare*.
- 1850. 11. Hone, Nathaniel, M.R.I.A., *St. Doulough's, Co. Dublin*.
- 1861. 12. Hone, Thomas, *Yapton, Monkstown, Co. Dublin*.
- 1831. 13. Hutton, Robert, F.G.S., *Putney Park, London*.
- 1867. 14. Kane, Sir R., 76, *Harcourt-street*.
- 1866. 15. Lalor, J. J., 6, *Upper Fitzwilliam-street*.
- 1856. 16. Lentaigue, John, M.D., 6, *Great Denmark-street*.
- 1851. 17. Malahide, Lord Talbot de, F.R.S., *Malahide Castle, Malahide*.
- 1867. 18. Malet, Rev. J. A., D.D., S.F.T.C.D., *Trinity College*.
- 1838. 19. Mallet, Robert, C.E., F.R.S., *The Grove, Clapham-road, London*.
- 1846. 20. Murray, B. B., *County Survey Office, Downshire-road, Newry*.
- 1872. 21. O'Brien, William, *Ailesbury House, Merrion, Co. Dublin*.
- 1852. 22. O'Kelly, Joseph, 14, *Hume-street*.
- 1849. 23. Sidney, F. J., LL.D., 19, *Herbert-street*.
- 1864. 24. Symes, Richard Glascott, 14, *Hume-street*.
- 1851. 25. Whitty, John Irvine, LL.D.

FELLOWS WHO HAVE PAID HALF LIFE COMPOSITION.*

- 1868. 1. Backhouse, Henry, 2, *Ontario-terrace*.
- 1866. 2. Bradley, Samuel, *Little Castle, Castlecomer*.
- 1832. 3. Bryce, James, LL.D., M.A., F.G.S., *High School, Glasgow*.
- 1862. 4. Carter, T. S., *Watlington Park, Watlington, Oxfordshire*.
- 1854. 5. Clemes, John.
- 1870. 6. Cooke, Samuel, C.E., *Poona, Civil Engineering College, Bombay*.
- 1857. 7. Crawford, Robert, C.E.

* EXTRACT FROM BY-LAWS.

"Any person not residing for more than sixty-three days in each year within twenty miles of Dublin shall be a Fellow for Life, or until he comes to reside within the above distance, on paying to the Treasurers the sum of £5 5s.

"Any non-resident Life Fellow who shall reside within twenty miles of Dublin for more than sixty-three days in any one year, shall cease to be a Fellow, unless he shall either pay an additional composition of £5 5s., or shall pay a subscription of 10s. 6d. for each year in which he shall so reside for more than sixty-three days."

Elected.

- 1861. 8. Crosbie, William, *Ardfert Abbey, Ardfert, Tralee.*
- 1866. 9. Duffin, W. E. L'Estrange, *Co. Survey Office, Limerick.*
- 1861. 10. Dunally, Lord, *Kilboy, Nenagh.*
- 1866. 11. Ellis, R. H.
- 1871. 12. Emerson, Rev. J. M., *Timahoe.*
- 1869. 13. Enniskillen, Earl of, F.R.S., M.R.I.A., *Florence Court, Enniskillen.*
- 1872. 14. Gore, J. E., *Puttiala, Punjab, India.*
- 1871. 15. Hardman, E. T., 14, *Hume-street.*
- 1853. 16. Harkness, Professor, F.R.S., *Queen's College, Cork.*
- 1861. 17. Harte, W., C.E., *Buncrana, Donegal.*
- 1856. 18. Haughton, Lieut. John, R.A., *Bengal.*
- 1850. 19. Head, Henry, M.D., 7, *Fitzwilliam-square.*
- 1858. 20. Hill, J., C.E., *Ennis, Co. Clare.*
- 1862. 21. Hudson, R., F.R.S., F.L.S., *Clapham Common, London.*
- 1865. 22. Jacob, Arthur, B.A.
- 1839. 23. James, Sir H., Colonel, R.E., F.R.S., *Ordnance Survey Office, Southampton.*
- 1832. 24. Kearney, Thomas, *Pallasgreen, Co. Limerick.*
- 1857. 25. Keane, Marcus, *Beech Park, Ennis, Co. Clare.*
- 1853. 26. Kinahan, George H., 14, *Hume-street.*
- 1862. 27. Kincaid, Joseph, Jun., C.E., 9, *Spring Gardens, London, S. W.*
- 1838. 28. Larcom, Major-General Sir Thomas, R.E., LL.D., F.R.S., *Heathfield, Fareham, Hants.*
- 1858. 29. Leech, Lieut.-Colonel, R.E., 3, *St. James's-square, London, S. W.*
- 1868. 30. Leonard, Hugh, 14, *Hume-street.*
- 1840. 31. Lindsay, Henry L., C.E., *Melbourne, care of J. Bower, Esq., C.E., 28, South Frederick-street.*
- 1867. 32. Meadows, J. McCarthy, 18, *Upper Gloucester-street.*
- 1840. 33. Montgomery, James E., M.R.I.A.
- 1856. 34. Moloney, C. P., Capt. 25th Regiment, Madras, N.I., *per Messrs. Grindlay and Co., 3, Cornhill, London.*
- 1856. 35. Medlicott, Henry B., F.G.S., *Geological Survey of India, per Smith and Elder, Cornhill, London, E.C.*
- 1857. 36. M'Ivor, Rev. James, *Rectory, Moyle, Newtownstewart, Co. Tyrone.*
- 1865. 37. Morton, G. H., 122, *London-road, Liverpool.*
- 1845. 38. Neville, John, C.E., M.R.I.A., *Dundalk.*
- 1870. 39. Nicolls, Thomas, 11, *Elizabeth-street, Manchester.*
- 1868. 40. Nolan, Joseph, 14, *Hume-street.*
- 1832. 41. Renny, Henry L., R.E., *Canada.*
- 1870. 42. Rigby, Jason, C.E., 49, *Park-avenue, Sandymount.*
- 1865. 43. Scott, J. M., *Bengal Presidency College, Calcutta.*
- 1854. 44. Scott, R. H., *Meteorological Office, 116, Victoria-street, London.*
- 1872. 45. Sharpe, R. W., *Redbay Pier and Harbour Works, Cushendall, Larne.*
- 1868. 46. Siree, P. H., C.E.
- 1854. 47. Smyth, W. W., F.R.S., *Jermyn-street, London.*
- 1865. 48. Steele, Rev. W., *Portora Royal School, Enniskillen.*
- 1871. 49. Sturman, Dr. E. A., *Queen's College, Anerley, Sydenham, London.*
- 1857. 50. Tate, Alexander, C.E., *Queen's Elms, Belfast.*
- 1870. 51. Taylor, J. E., F.G.S., *Bracondale, Norwich.*
- 1832. 52. Tighe, Right Hon. William, *Woodstock, Innistiogue.*
- 1866. 53. Townsend, H. W., *Clonakilty.*
- 1871. 54. Traill, William A., 14, *Hume-street.*
- 1866. 55. Wall, H. P., *Portarlinton.*
- 1864. 56. Waller, G. A.
- 1853. 57. Webster, William B.
- 1871. 58. Weldon, Captain Frank.

Elected.

1872. 59. White, John N., *Waterford*.
 1861. 60. Whitney, C. J., *Brisbane, Queensland*.
 1846. 61. Wilson, Walter.
 1864. 62. Wright, Joseph, *Cliftonville, Antrim-road, Belfast*.
 1854. 63. Wyley, Andrew.
 1857. 64. Wynne, Arthur B., F.G.S., *Geological Survey of India, Calcutta*.

FELLOWS.

1861. 1. Andrews, William, *Ashton, The Hill, Monkstown*.
 1867. 2. Baily, W. H., 14, *Hume-street*.
 1857. 3. Bandon, Earl of, D.C.L., *Castle Bernard, Bandon, Co. Cork*.
 1859. 4. Barker, John, M.D., 83, *Waterloo-road*.
 1861. 5. Barrington, C. E., *Fassaroe, Bray*.
 1862. 6. Barrington, E., *Fassaroe, Bray*.
 1862. 7. Barton, Henry M., 4, *Foster-place*.
 1844. 8. Bective, Earl of, *Headfort, Kells*.
 1862. 9. Bennett, E. H., M.D., 26, *Lower Fitzwilliam-street*.
 1872. 10. Bennett, F. J., 28, *Jermyn-street, London*.
 1857. 11. Bolton, George, Jun., 6, *Ely-place*.
 1861. 12. Bolton, H. E., 6, *Ely-place*.
 1868. 13. Brien, Charles H., *Board of Public Works, Custom-house*.
 1870. 14. Brett, H. C., C.E.
 1872. 15. Budds, Rev. Thomas, 10, *Garville Avenue, Rathgar-road*.
 1857. 16. Carte, Alexander, M.D., F.L.S., *Royal Dublin Society*.
 1867. 17. Clarke, G. R., *Public Works Department, Lucknow, India*.
 1862. 18. Close, Rev. Maxwell, *Newtown Park, Blackrock*.
 1872. 19. Coffey, Francis, C.E., *The Retreat, Kilkee*.
 1858. 20. Cotton, Charles P., C.E., 11, *Lower Pembroke-street*.
 1862. 21. Cousins, A. L., C.E.
 1863. 22. Crook, Rev. R., LL.D., *Wesleyan College, Belfast*.
 1868. 23. Cruise, R. J., 14, *Hume-street*.
 1853. 24. De Vesci, Lord, *Abbeyleix House, Abbeyleix*.
 1849. 25. Downing, Samuel, LL.D., C.E., *Trinity College*.
 1852. 26. Doyle, J. B., *Derrymore House, Newry*.
 1867. 27. Dunscombe, Clement, *King William's Town, Co. Cork*.
 1872. 28. Egan, F. W., 14, *Hume-street*.
 1865. 29. Fleming, John M., *Alderney, Channel Islands*.
 1866. 30. Foot, A. W., M.D., 21, *Lower Pembroke-street*.
 1867. 31. Forster, R.
 1858. 32. Gages, Alphonse, M.R.I.A., 51, *Stephen's-green*.
 1849. 33. Galbraith, Rev. Joseph A., F.T.C.D., *Trinity College*.
 1865. 34. Gibson, John, C.E., *Stapleton-place, Dundalk*.
 1867. 35. Gore, J. E., C.E., *Puttiala, Punjab, India*.
 1862. 36. Gribbon, C. P., 72, *Stephen's-green*.
 1831. 37. Griffith, Sir R., Bart., LL.D., F.G.S., 2, *Upper Fitzwilliam-place*.
 1857. 38. Hampton, Thomas, C.E., 6, *Ely-place*.
 1866. 39. Heron, Robert, *Harrow House, Ballybrack*.
 1861. 40. Hudson, A., M.D., 2, *Merriion-square, North*.
 1870. 41. Hull, Edward, M.A., F.R.S., 14, *Hume-street*.
 1865. 42. Hutton, T. M., 118, *Summer-hill*.
 1852. 43. Jellett, Rev. J., F.T.C.D., M.R.I.A., 9, *Trinity College*.
 1842. 44. Jennings, F. M., M.R.I.A., *Brown-street, Cork*.
 1871. 45. Kelly, G. N. H., *Fair-street, Drogheda*.
 1862. 46. Kinahan, G., J.P., *Roebuck-hill, Dundrum*.
 1866. 47. Knapp, W. H., C.E., 5, *Summerhill-road, Kingstown*.

APPENDIX.

V

Elected.

1865. 48. Leech, John, C.E., 6, *Ely-place*.
 1831. 49. Lloyd, Rev. Humphrey, D.D., F.R.S., Provost T.C.D., *Provost's House*.
 1863. 50. Macalister, A., M.B., 5, *Trinity College*.
 1861. 51. M'Comas, A., *Cliff Castle, Dalkey*.
 1863. 52. M'Donnell, Alexander, C.E., *St. John's, Inchicore*.
 1851. 53. M'Donnell, John, M.D., 4, *Gardiner's-row*.
 1837. 54. Mollan, John, M.D., 8, *Fitzwilliam-square*.
 1859. 55. Moore, Joseph Scott, J.P., 12, *Hume-street*.
 1831. 56. Nicholson, John, M.R.I.A., *Balrath House, Kells*.
 1856. 57. O'Brien, Octavius, 23, *Kildare-street*.
 1871. 58. O'Leary, W. H., M.D., 38, *York-street, Dublin*.
 1864. 59. Palmer, Sandford, *Roscrea*.
 1857. 60. Porter, William, C.E.
 1865. 61. Radley, John, *Gresham Hotel, Sackville-street*.
 1864. 62. Reynolds, J. Emerson, M.D., 52, *Upper Leeson-street*.
 1857. 63. Reeves, R. S., 22, *Upper Mount-street*.
 1861. 64. Roberts, W. G., *Nenagh, Co. Tipperary*.
 1862. 65. Rowan, D. J., O.E., *Athlone*.
 1864. 66. Russell, H.
 1861. 67. Stoney, Bindon, C.E., 42, *Wellington-road*.
 1852. 68. Taylor, Colonel Meadows, M.R.I.A., *Oldcourt, Harold's-cross*.
 1864. 69. Tichborne, C. R. C., *Apothecaries' Hall, Mary-street*.
 1869. 70. Traquair, R. H., M.D.
 1859. 71. Waldron, L., LL.D., *Ballydrack*.
 1863. 72. Westropp, W. H. S., M.R.I.A., *Lisdoonvarna, Co. Clare*.
 1872. 73. Wilkinson, Sydney B., 14, *Hume-street*.
 1863. 74. Williams, Richard Palmer, 38, *Dame-street*.
 1872. 75. White, H. V., C.E.
 1851. 76. Wright, Edmund P., LL.D., M.R.I.A., 5, *Trinity College, Dublin*.

No. II.

LIST OF MEMBERS ELECTED IN 1873.

- | | |
|-------------------------------|-----------------------------|
| 1. Wm. Berry Greening. | 7. T. Rupert Jones, F.R.S. |
| 2. J. Allison Readwin. | 8. J. Townsend Trench. |
| 3. A. C. Johnston, M.R.C.S. | 9. T. Rowney, Ph.D. |
| 4. J. A. Cooper, M.D. | 10. R. O. Cunningham, Ph.D. |
| 5. Thomas Mayne. | 11. Josiah Dobbs. |
| 6. Frederick Broughton, LL.D. | 12. Charles Cox. |

No. III.

State of the Society :—

		Last Report.	Present Year.
Honorary Fellows	.....	13	13
Corresponding do.	.....	6	6
Life	do.	91	101
Annual	do.	86	76
		196	196

No. IV.

SOCIETIES AND INSTITUTIONS TO WHICH THE JOURNAL OF THE
ROYAL GEOLOGICAL SOCIETY OF IRELAND IS SENT.

ABERDEEN ...	University Library.
ALBANY.....	State Library, New York.
AMSTERDAM...	Royal Academy of Sciences.
ANTWERP	Société Paléontologique de Belgique.
BELFAST	Queen's College Library. Naturalists' Field Club.
BERLIN.....	Royal Academy of Sciences. German Geographical Society. German Geological Society, per Bessersche Buchhandlung, <i>Behren-</i> <i>strasse, 7, Berlin.</i>
BOLOGNA	Accademia delle Scienze dell' Instituto.
BORDEAUX ...	Imperial Academy of Sciences.
BOSTON	American Academy. Natural History Society.
BRISTOL.....	Institution for the Advancement of Science, Literature, and the Arts.
BRÜNN	Naturforschende Verein.
BRUSSELS	Academy of Sciences.
CAEN	Société Linnéenne Normandie.
CALCUTTA ...	Asiatic Society. Public Library. Geological Survey of India.
CAMBRIDGE ...	Philosophical Society. Trinity College Library.
CANTERBURY, NEW ZEA- LAND	} Geological Survey.
COPENHAGEN.	
CORK	Royal Society of Science. Queen's College Library. Royal Institution.
DIJON	Academy of Sciences.
DRESDEN	The "Isis" Society.
DUBLIN	Royal College of Surgeons' Library. Royal Irish Academy. University Library. Royal Dublin Society. Natural History Society. Ordnance Survey Library. Professor Sullivan, as Editor of the "Atlantis." Geological Survey of Ireland. Institution of Civil Engineers.
EDINBURGH ...	Royal Society. Royal Scottish Society of Arts. University Library. Society of Antiquaries. Advocates' Library.
FALMOUTH ...	Royal Cornwall Polytechnic Society.
FLORENCE.....	Society of Physics and Natural History.
GALWAY	Queen's College Library.
GENOA	Society of Physics.
GLASGOW	University. Geological Society.

- GÖTTINGEN ... University.
 HAARLEM Société Hollandaise des Sciences, per B. Quaritch, 15, *Piccadilly, London.*
 HALLE Naturwissenschaftliche Verein für Sachsen und Thüringen, per Antons Buchhandlung, *Halle.*
 HANAU Oberhessische Gesellschaft der Natur- und Heil-kunde.
 HANOVER Royal Library.
 KILKENNY ... Archæological Society.
 KÖNIGSBERG... Königlich Physicalisch-Oekonomische Gesellschaft.
 LAUSANNE ... Société Vaudois des Sciences Naturelles.
 LEEDS Geological and Polytechnic Society of the West Riding of Yorkshire.
 LEIPSIK Philosophical and Literary Society.
 LEIPSIK Royal Society of Sciences (Saxony).
 LEIPSIK University.
 LIVERPOOL ... The Literary and Philosophical Society.
 LIVERPOOL ... Historical Society of Lancashire and Cheshire.
 LIVERPOOL ... Geological Society, The Royal Institution, *Colquitt-street.*
 LONDON..... Geological Survey, *Jermyn-street.*
 LONDON..... British Museum.
 LONDON..... Society of Arts, *John-street, Adelphi.*
 LONDON..... Royal Institution, *Albemarle-street.*
 LONDON..... Royal Society, *Burlington House.*
 LONDON..... Geological Society, *Burlington House.*
 LONDON..... Linnean Society, *Burlington House.*
 LONDON..... Royal Geographical Society, 15, *Whitehall-place.*
 LONDON..... Civil Engineers, Institution of, 25, *Great George-street, Westminster.*
 LONDON..... Royal Asiatic Society, 22, *Albemarle-street.*
 LONDON..... Royal College of Surgeons, *Lincoln's Inn.*
 LONDON..... Zoological Society, 11, *Hanover-square.*
 LONDON..... Athenæum, 14, *Wellington-street, Strand, London, W.C.*
 LONDON..... Anthropological Society, 4, *St. Martin's-place, London, W.C.*
 LYONS La Société Impériale d'Agriculture, d'Histoire Naturelle, et des Arts Utiles.
 LYONS Société Linnéenne.
 LYONS Académie Impériale, per Treuttel & Wurtz, 19, *Rue de Lille, Paris.*
 MADRID..... Academia de Ciencias.
 MANCHESTER. Literary and Philosophical Society of.
 MANCHESTER. Geological Society.
 MELBOURNE... Philosophical Institute of Victoria.
 MELBOURNE... The Public Library, per Bain and Co., 1, *Haymarket, London.*
 MELBOURNE... The Royal Society.
 MILAN Reale Istituto Lombardo di Scienze.
 MISSOURI State Survey and University, *Geological Rooms, Columbia, U.S.A.*
 MODENA Institute of Science.
 MONTREAL ... Natural History Society.
 MUNICH..... Royal Academy of Science (2 copies).
 NEUCHÂTEL... Société des Sciences Naturelles.
 NEW HAVEN, } The Editors of Silliman's Journal of Science and Art.
 U. S. A. }
 NEW YORK ... Lyceum of Natural History.
 OXFORD Bodleian Library.
 OXFORD Ashmolean Society.
 PALERMO Accademia di Scienze e Lettere.
 PARIS Ecole Polytechnique.
 PARIS Geological Society.
 PARIS L'Ecole Impériale des Mines.

viii JOURNAL OF THE ROYAL GEOLOGICAL SOCIETY OF IRELAND.

PARIS	Institute of France. Bibliothèque Impériale. Jardin des Plantes, Bibliothèque.
PHILADELPHIA.	American Philosophical Society. Academy of Natural Sciences, per Trübner and Co.
PLYMOUTH ...	The Plymouth Institution and Devon and Cornwall Natural History Society.
PRESBURG	Der Verein für Naturkunde.
QUEBEC	Literary and Historical Society.
ROME	The Vatican Library.
ROUEN	Academy of Sciences.
ST. ANDREWS.	University Library.
ST. LOUIS	Academy of Sciences.
ST. PETERSBURG	Imperial Academy. Central Physical Observatory of Russia. Russisch-Kaiserliche Mineralogische Gesellschaft.
STOCKHOLM ...	Royal Academy of Science, per Longman and Co., <i>Paternoster-row, London</i> ; and Sampson and Wallis, <i>Stockholm</i> . Geological Survey of Sweden.
STRASBURG ...	Société des Sciences Naturelles.
STUTTGART ...	Verein für vaterländische Naturkunde.
TORONTO, C.W.	Canadian Institute, per Thomas Henning, Esq.
TOULOUSE	Academy of Sciences.
TRURO	Royal Institute of Cornwall.
TURIN	Royal Academy.
UPSALA	Royal Society of Sciences.
VIENNA	Imperial Academy of Sciences. Prof. W. Haidinger, of Vienna, as Editor of the "Jahrbuch der k. k. Geologischen Reichsanstalt." K. k. Zoologisch-botanische Gesellschaft, per Braumüller and Co., <i>Vienna</i> .
WASHINGTON.	Smithsonian Institute Library, per W. Wesley, Esq., 28, <i>Essex-street, Strand, London</i> .
WINDSOR	The Royal Library.
ZURICH	Naturforschende Gesellschaft.

No. V.

ABSTRACT OF TREASURER'S ACCOUNTS FOR THE YEAR ENDING 31st DECEMBER, 1873.

Ck.

Dr.

1872.	£ s. d.		1873.	£ s. d.
To Balance in Royal Bank to 31st Dec. 1872 ...	£28 18 8		Jan. 2	4 19 6
" Deduct Subscriptions for 1873 included ...	3 1 0		March 5	5 0 0
" Received from Collector Arrears for 1872 ...	...	25 17 8		5 0 0
" Life Compositions for 1873 ...	47 5 0	6 2 0	April 2	2 0 0
" Entrance Fees ...	4 4 0			1 15 0
" Annual Subscriptions ...	55 1 0		May 7	2 10 0
" Received Dividends to 5th April, 1873, on £381 16 5 Stock...	...	106 10 0		21 1 3
" Ditto ...	5 9 5			2 0 0
" Ditto ...	0 8 4		June 4	5 5 0
" Ditto to 5th October, 1873, on £387 9 1 ...	5 13 8	5 17 9		5 5 0
" Ditto ...	0 1 8			8 2 0
" Received from Francis Coffee, on Cheque 7th Nov. ...	...	5 14 9	June 25	3 3 1
		0 0 3		7 12 6
			1874-	4 13 9
			Jan. 7	1 17 6
				4 1 8
				5 0 0
				5 0 0
				66 1 2
				£150 2 5

By M. H. Gill's Account for Printing Sundries ...	£5 8 2		£ s. d.
" Williams & Sons, Purchase of Stock for R. Scott ...			4 19 6
" Connor's Wages for January and February ...			5 0 0
" G. Hanlon, for Woodcuts ...			2 0 0
" Alfred Ormsby, balance of Salary ...			1 15 0
" M. H. Gill, for Printing ...			2 10 0
" John Connor ...			21 1 3
" Half Life Composition of E. T. Hardman, Stock Purchased ...	5 13 8		2 0 0
" Rev. Dr. Haughton, Petty Expenses ...			5 5 0
" Mr. Edward Leeson, Assistant Secretary, half- year to 30th June ...	2 10 0		8 2 0
" Postages, &c. ...	0 13 1		
" Mr. George Hanlon, Illustrations ...			3 3 1
" Messrs. Foster and Co. ...			7 12 6
" Mr. George Hanlon, Illustrations ...			4 13 9
" Rev. Dr. Haughton, Petty Expenses ...			1 17 6
" Remitted to E. Cooke, Esq., Annual Subscription of the late Henry Cooke ...			4 1 8
" Mr. Edward Leeson, Assistant Secretary ...			5 0 0
" Balance of this Account ...			5 0 0
			66 1 2
			£150 2 5

Examined and found correct,

Feb. 4, 1874.

W. FRAZER.

APPENDIX.



APPENDIX.

LIST OF FELLOWS, CORRECTED TO OCTOBER 31, 1877.

Fellows are requested to correct errors in this List, by Letter to the
REV. DR. HAUGHTON, Treasurer, Trinity College, Dublin.

OFFICERS OF THE SOCIETY FOR THE YEAR 1877-8.

PRESIDENT.—Rev. Maxwell Close, F. G. S.

VICE-PRESIDENTS.—Earl of Enniskillen, F. R. S., F. G. S.; Sir Richard Griffith, Bart., LL.D., F. R. S. E.; Professor E. Hull, F. R. S., F. G. S.; Sir Robert Kane, LL.D., M. D., F. R. S.; Rev. H. Lloyd, Provost, T. C. D., D. D., F. R. S.

TREASURERS.—Rev. Samuel Haughton, M. D.; Professor Samuel Downing, LL.D.

SECRETARIES.—Professor J. Emerson Reynolds, Ph. D., F. C. S.; Prof. A. Macalister, M. D.

COUNCIL.—Alexander Carte, M. D.; W. Frazer, F. R. C. S. I.; Alphonse Gages, M. R. I. A.; Edward Hardman, F. C. S.; Prof. Harkness, F. R. S., F. G. S.; T. Maxwell Hutton; Francis M. Jennings, F. C. S.; George H. Kinahan; Hugh Leonard, F. G. S., M. R. I. A.; Joseph O'Kelly; George Porte, M. R. I. A.; Robert S. Reeves; B. B. Stoney, C. E.; C. R. C. Tichborne, Ph. D., M. R. I. A.; W. H. S. Westropp, M. D., M. R. I. A.

HONORARY FELLOWS.

Elected.

1844. 1. Boué, M. Ami, For. Mem. L. G. S., M. D., *Académie Imp. Sc., Vienna.*
1865. 2. Burton, Captain R. F., *Royal Geographical Society, 1, Savile Row, London.*
1861. 3. Daubrée, M., Membre de l'Institut, 91, *Rue de Gréville, St. Germain, Paris.*
1861. 4. Delesse, M., Ingénieur des Mines, *Paris.*
1865. 5. Des Cloiseaux, M., Prof. of Mineralogy, *Jardin des Plantes, Paris.*
1861. 6. De Serres, M. Marcel, *Montpellier.*
1861. 7. Deville, M. C. Ste.-Claire, 8, *Rue des Vieux Colombières, Paris.*
1861. 8. Deville, M. H. Ste.-Claire, 8, *Rue des Vieux Colombières, Paris.*
1861. 9. De Koninck, M. L., For. Mem. L. G. S., *Liège.*
1861. 10. Geinitz, M. H. B., For. Mem. L. G. S., *Dresden.*
1863. 11. Hunt, Dr. T. Sterry, F. R. S., *Institute of Technology, Boston, U. S.*
1873. 12. Jones, Professor T. Rupert, F. R. S., 5, *College Terrace, Yorktown, Surrey.*
1861. 13. McClintock, Rear-Admiral Sir Leopold, R. N., C. B., F. R. S., *Dock-yard, Portsmouth.*

HONORARY CORRESPONDING FELLOWS.

Elected.

- 1859. 1. Gordon, John, C. E., *India*.
- 1859. 2. Hargrave, Henry J. B., C. E., *India*.
- 1859. 3. Hime, John, C. E., *Ceylon*.
- 1858. 4. Kingsmill, Thomas W., *Hong Kong*.
- 1855. 5. Medicott, Joseph, *India*.
- 1854. 6. Oldham, Thomas, F. R. S., *Calcutta*.

FELLOWS WHO HAVE PAID LIFE COMPOSITION.

- 1853. 1. Allen, Richard Purdy, Chelmsford House, Angell Road, Brixton, London, S. W.
- 1861. 2. Armstrong, Andrew, 16, *D'Olier-street*.
- 1857. 3. Carson, Rev. Joseph, D. D., S. F. T. C. D., *Trinity College*.
- 1857. 4. Dowse, Rt. Hon. Baron, *Mountjoy-square*.
- 1872. 5. Durham, J. S. W., *Rosenthal, Torquay, Devon*.
- 1861. 6. Fottrell, Edward, *Drayton, Cambridge-road, Rathmines*.
- 1862. 7. Frazer, W., F. R. C. S. I., 20, *Harcourt-street*.
- 1857. 8. Greene, John Ball, 6, *Ely-place*.
- 1848. 9. Haughton, Rev. Professor, M. D., F. R. S., 40, *Trinity College*.
- 1862. 10. Henry, F. H., *Lodge Park, Straffan, county Kildare*.
- 1850. 11. Hone, Nathaniel, M. R. I. A., *St. Doulough's, county Dublin*.
- 1867. 12. Kane, Sir Robert, F. R. S., 15, *Raglan-road, Dublin*.
- 1866. 13. Lalor, J. J., 6, *Upper Fitzwilliam-street*.
- 1856. 14. Lentaigue, John, M. D., 6, *Great Denmark-street*.
- 1851. 15. Malahide, Lord Talbot de, F. R. S., *Malahide Castle, Malahide*.
- 1867. 16. Malet, Rev. J. A., D. D., S. F. T. C. D., *Trinity College*.
- 1838. 17. Mallet, Robert, C. E., F. R. S., *The Grove, Clapham-road, London*.
- 1876. 18. Mayne, Thomas, 2, *Glenart Avenue, Blackrock, Co. Dublin*.
- 1846. 19. Murray, B. B., *County Survey Office, Downshire-road, Newry*.
- 1872. 20. O'Brien, William, *Ailesbury House, Merrion, county Dublin*.
- 1852. 21. O'Kelly, Joseph, 14, *Hume-street*.
- 1857. 22. Porter, William, C. E.
- 1849. 23. Sidney, F. J., LL.D., 19, *Herbert-street*.
- 1864. 24. Symes, Richard Glascott, 14, *Hume-street*.
- 1851. 25. Whitty, Rev. John Irvine, LL.D., 94, *Lower Baggot-street*.

FELLOWS WHO HAVE PAID HALF LIFE COMPOSITION.*

- 1868. 1. Backhouse, Henry, 2, *Ontario-terrace*.
- 1875. 2. Boot, John Thomas, *Hucknall, Mansfield*.
- 1866. 3. Bradley, Samuel, *Little Castle, Castlecomer*.
- 1873. 4. Broughton, Frederick, LL.D., *Hamilton, Ontario*.
- 1862. 5. Carter, T. S., *Watlington Park, Watlington, Oxfordshire*.
- 1867. 6. Clark, George R., C. E., *Northern Bengal State Railway, Parbatipur, Dinagepore, Bengal*.
- 1854. 7. Clemes, John.

* EXTRACT FROM BY-LAWS.

"Any person not residing for more than sixty-three days in each year within twenty miles of Dublin shall be a Fellow for Life, or until he comes to reside within the above distance, on paying to the Treasurers the sum of £5 5s.

"Any non-resident Life Fellow who shall reside within twenty miles of Dublin for more than sixty-three days in any one year shall cease to be a Fellow, unless he shall either pay an additional composition of £5 5s., or shall pay a subscription of 10s. 6d. for each year in which he shall so reside for more than sixty-three days.

- Elected.
1870. 8. Cooke, Samuel, C. E., *Civil Engineering College, Poona, Bombay.*
 1873. 9. Cooper, J. A., M.D., *Civil Surgeon of Hissar Hissar, Bengal.*
 1873. 10. Cox, Charles C., *Ashby House School, Walsall.*
 1857. 11. Crawford, Robert, C. E.
 1861. 12. Crosbie, William, *Ardfert Abbey, Ardfert, Tralee.*
 1868. 13. Cruise, Richard J., *Geological Survey, 14, Hume-street, Dublin.*
 1873. 14. Cunningham, Professor R. O., M. D. Edin., *Queen's College, Belfast.*
 1874. 15. Devine, Thomas, *Deputy Surveyor General for Ontario, Toronto, Canada.*
 1873. 16. Dobbs, Josiah, *Coolbaun, Castlecomer, Kilkenny.*
 1866. 17. Duffin, W. E. L'Estrange, *County Survey Office, Limerick.*
 1861. 18. Dunally, Lord, *Kilboy, Nenagh.*
 1876. 19. Dunscombe, Clement, M. A., C. E., *Public Offices, Derby.*
 1872. 20. Egan, F. W., 14, *Hume-street.*
 1866. 21. Ellis, R. H.
 1871. 22. Emerson, Rev. J. M., *Timahoe, Abbeyleix.*
 1869. 23. Enniskillen, Earl of, F. R. S., M. R. I. A., *Florence Court, Enniskillen.*
 1872. 24. Gore, J. E., *care of C. S. Rundle, Esq., C. E., Umballa Post-office, Punjab, India.*
 1871. 25. Hardman, E. T., 14, *Hume-street.*
 1853. 26. Harkness, Professor, F. R. S., *Queen's College, Cork.*
 1861. 27. Harte, W., C. E., *Donegal County Surveyor, Office, Londonderry.*
 1856. 28. Haughton, Major John, R. A., *Bengal.*
 1850. 29. Head, Henry, M. D., 7, *Fitzwilliam-square.*
 1858. 30. Hill, J., C. E., *Ennis, county Clare.*
 1862. 31. Hudson, R., F. R. S., F. L. S., *Clapham Common, London.*
 1839. 32. James, Sir H., Major-General R. E., F. R. S., *Ordnance Survey Office, Southampton.*
 1857. 33. Keane, Marcus, *Beech Park, Ennis, county Clare.*
 1871. 34. Kelly, G. N. H., *Fair-street, Drogheda.*
 1862. 35. Kinahan, G., J. P., *Roebuck Hill, Dundrum, county Dublin.*
 1853. 36. Kinahan, George H., 14, *Hume-street.*
 1862. 37. Kincaid, Joseph, Jun., C. E.
 1838. 38. Larcom, Major-General Sir Thomas, R. E., LL.D., F.R.S., *Heathfield, Fareham, Hants.*
 1874. 39. Laurence, Rev. Chas., *Lisreaghan, Laurecetown, county Galway.*
 1858. 40. Leach, Lieut.-Colonel, R. E., 3, *St. James's-square, London, S. W.*
 1868. 41. Leonard, Hugh, 14, *Hume-street.*
 1875. 42. Lilley, Rev. Charles, M. A., *Head Master of Ware Grammar School, Ware, Herts.*
 1840. 43. Lindsay, Henry L., C. E., *Melbourne, care of J. Bower, Esq., C. E., 28, South Frederick-street.*
 1867. 44. Meadows, J. M'Carthy.
 1874. 45. Meadows, Joseph, Jun., *Thornville, county Wexford.*
 1840. 46. Montgomery, James E., M. R. I. A.
 1856. 47. Moloney, C. P., *Capt. 25th Regiment, Madras N. I., per Messrs. Grindlay and Co., 3, Cornhill, London.*
 1856. 48. Medlicott, Henry B., F. G. S., *Geological Survey of India, per Smith and Elder, Cornhill, London, E. C.*
 1857. 49. M'Ivor, Rev. James, *Rectory, Moyle, Newtownstewart, county Tyrone.*
 1865. 50. Morton, G. H., 122, *London-road, Liverpool.*
 1845. 51. Neville, John, C. E., M. R. I. A., *Dundalk.*
 1870. 52. Nicolls, Thomas, C. E., *Resident Engineer, Yorkshire and Lancashire Railway, Manchester.*
 1868. 53. Nolan, Joseph, 14, *Hume-street.*
 1832. 54. Renny, Henry L., R. E., *Canada.*
 1870. 55. Rigby, Jason, C. E., 49, *Park-avenue, Sandymount.*
 1873. 56. Rowney, Professor T., Ph. D., *Queen's College, Galway.*

Elected.

1875. 57. Scholfeld, Amos, M. A., *Clyde Cottage, Redland Vale, Bristol.*
 1854. 58. Scott, R. H., M. A., F. R. S., *Meteorological Office, 116, Victoria-street, London.*
 1872. 59. Sharpe, R. W., *Redbay Pier and Harbour Works, Cushendall, Larne.*
 1868. 60. Siree, P. H., C. E.
 1854. 61. Smyth, W. W., F. R. S., *Jermyn-street, London.*
 1865. 62. Steele, Rev. W., *Portora Royal School, Enniskillen.*
 1871. 63. Sturman, Dr. E. A., *Queen's College, Penge, London, S. E.*
 1857. 64. Tate, Alexander, C. E., *Queen's Elms, Belfast.*
 1870. 65. Taylor, J. E., F. G. S., *Bracondale, Norwich.*
 1832. 66. Tighe, Right Hon. William, *Woodstock, Innistiogue.*
 1866. 67. Townsend, H. W., *Clonakilty.*
 1871. 68. Traill, William A., *Geol. Survey, Ballymena, Co. Antrim.*
 1873. 69. Trench, J. Townsend, *Kenmare.*
 1866. 70. Wall, H. P., *Portarlinton.*
 1864. 71. Waller, G. A., 2, *Longford-terrace, Monkstown, county Dublin.*
 1853. 72. Webster, William B.
 1871. 73. Weldon, Captain Frank.
 1872. 74. White, H. V., C. E., *County Surveyor, Longford.*
 1872. 75. White, John N., *Waterford.*
 1876. 76. Whiston, William, M. A., *Collegiate Academy, Chapel-Chorlton, near Newcastle, Staffordshire.*
 1861. 77. Whitney, C. J., *Brisbane, Queensland.*
 1846. 78. Wilson, Walter.
 1864. 79. Wright, Joseph, *Cliftonville, Antrim-road, Belfast.*
 1854. 80. Wyley, Andrew.
 1857. 81. Wynne, Arthur B., F. G. S., *Geological Survey of India, Calcutta.*

ANNUAL FELLOWS.

1875. 1. Adams, Professor A. Leith, M. B., F. R. S., *Royal College of Science, Stephen's-green.*
 1861. 2. Barrington, E. E., M. B., *Enniskerry.*
 1862. 3. Barton, Henry M., 4, *Foster-place.*
 1868. 4. Brien, Charles H., *Board of Public Works, Custom-house.*
 1872. 5. Byron, R., 2, *Fitzwilliam-place.*
 1857. 6. Carte, Alexander, M. D., F. L. S., *Royal Dublin Society.*
 1862. 7. Close, Rev. Maxwell, 40, *Lower Baggot-street, Dublin.*
 1858. 8. Cotton, Charles P., C. E., 11, *Lower Pembroke-street.*
 1874. 9. Crawley, J. Chetwode, B. A., 3, *Ely-place.*
 1849. 10. Downing, Samuel, LL.D., C. E., *Trinity College.*
 1876. 11. Fitt, Decimus, C. E., *Longford, or care of Messrs. Courtney and Stephens, Blackhall-place.*
 1865. 12. Fleming, John M., *Portsbridge Cottage, Cosham, Hants.*
 1866. 13. Foot, A. W., M. D., 21, *Lower Pembroke-street.*
 1858. 14. Gages, Alphonse, M. R. I. A., 51, *Stephen's-green.*
 1862. 15. Gribbon, C. P., 72, *Stephen's-green.*
 1831. 16. Griffith, Sir R., Bart., LL.D., F. G. S., 2, *Upper Fitzwilliam-place.*
 1857. 17. Hampton, Thomas, C. E., 6, *Ely-place.*
 1861. 18. Hudson, A., M. D., 2, *Merrion-square, North.*
 1870. 19. Hull, Edward, M. A., F. R. S., 14, *Hume-street.*
 1865. 20. Hutton, T. M., 118, *Summer-hill.*
 1852. 21. Jellett, Rev. J., F. T. C. D., M. R. I. A., 9, *Trinity College.*
 1842. 22. Jennings, F. M., M. R. I. A., *Brown-street, Cork.*
 1866. 23. Knapp, W. H., C. E., 17, *Belgrave-square, N., Monkstown, Co. Dublin.*
 1865. 24. Leitch, John, C. E., 6, *Ely-place.*
 1831. 25. Lloyd, Rev. Humphrey, D.D., F. R. S., *Provost T. C. D., Provost's House.*

SOCIETIES AND INSTITUTIONS TO WHICH THE JOURNAL OF
THE ROYAL GEOLOGICAL SOCIETY OF IRELAND IS SENT.

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AMSTERDAM ..	Royal Academy of Sciences.
ANTWERP ..	Palæontological Society of Belgium.
BELFAST ..	Queen's College Library.
	Naturalists' Field Club.
BERLIN ..	Royal Prussian Academy of Sciences.
	German Geographical Society.
	German Geological Society, per Bessersche Buchhandlung, <i>Behren-</i> <i>strasse, 7, Berlin.</i>
BOLOGNA ..	Academy of Sciences of the Institute.
BORDEAUX ..	Society of Physical and Natural Sciences.
BOSTON ..	American Academy of Arts and Sciences.
	Natural History Society.
BRISTOL ..	Institution for the Advancement of Science, Literature, and the Arts.
BRÜNN ..	Natural History Association.
BRUSSELS ..	Royal Academy of Sciences, Letters, and Fine Arts of Belgium.
CAEN ..	Linnæan Society of Normandy.
CALCUTTA ..	Asiatic Society.
	Public Library.
	Geological Survey of India.
CAMBRIDGE ..	Philosophical Society.
	Trinity College Library.
CANTERBURY, NEW ZEALAND ..	} Geological Survey.
COPENHAGEN ..	Royal Danish Academy of Science and Letters.
CORK ..	Queen's College Library.
	Royal Institution.
DIJON ..	Academy of Sciences, Arts, and Literature.
DRESDEN ..	"Isis" Natural History Society.
DUBLIN ..	Royal College of Surgeons' Library.
	Royal Irish Academy.
	University Library.
	Royal Dublin Society.
	Ordnance Survey Library.
	Geological Survey of Ireland.
	Institution of Civil Engineers.
EDINBURGH ..	Royal Society of Edinburgh.
	Edinburgh Geological Society.
	Royal Scottish Society of Arts.
	University Library.
	Society of Antiquaries.
	Advocates' Library.
FALMOUTH ..	Royal Cornwall Polytechnic Society.
FLORENCE ..	Italian Society of Sciences.
GALWAY ..	Queen's College Library.
GENEVA ..	Society of Physics and Natural History.
GLASGOW ..	University.
	Glasgow Geological Society.
GÜTTINGEN ..	University.
HALLE ..	Natural History Association for Saxony and Thuringia, per An- tons Buchhandlung, <i>Halle.</i>

- HANAU** .. Upper-Hessian Society of Natural and Medical Science.
HANOVER .. Royal Library.
HARLEM .. Dutch Society of Exact and Natural Sciences.
 Teyler Institution.
KILKENNY .. Archæological Association of Ireland.
KÖNIGSBERG .. Royal Physical and Economical Society.
LAUSANNE .. Vaudian Society of Natural Sciences.
LEEDS .. Geological and Polytechnic Society of the West Riding of Yorkshire.
 Philosophical and Literary Society.
LEIPSIK .. Royal Saxon Society of Sciences.
 University.
LIVERPOOL .. Literary and Philosophical Society.
 Historic Society of Lancashire and Cheshire.
 Liverpool Geological Society, The Royal Institution, *Colquitt-street*.
LONDON .. Geological Survey, *Jermyn-street*.
 British Museum.
 Society of Arts, *John-street, Adelphi*.
 Royal Institution, *Albemarle-street*.
 Royal Society, *Burlington House*.
 Geological Society, *Burlington House*.
 Linnæan Society, *Burlington House*.
 Royal Geographical Society, 15, *Whitehall-place*.
 Civil Engineers, Institution of, 25, *Great George-street, Westminster*.
 Royal Asiatic Society, 22, *Albemarle-street*.
 Royal College of Surgeons, *Lincoln's Inn*.
 Zoological Society, 11, *Hanover-square*.
 Geological Magazine, Editor of.
 Athenæum, 14, *Wellington-street, Strand, London, W. C.*
 Anthropological Society, 4, *St. Martin's-place, London, W. C.*
LYONS .. Society of Agriculture, Natural History, and Useful Arts.
 Linnæan Society.
 Academy of Sciences, Literature, and Arts, per Treuttel & Wurtz,
 19, *Rue de Lille, Paris*.
MADRID .. Royal Academy of Sciences.
 Geographical Society.
MANCHESTER .. Literary and Philosophical Society of.
 Manchester Geological Society.
MELBOURNE .. Philosophical Institute of Victoria.
 Public Library, per Bain and Co., 1, *Haymarket, London*.
 Royal Society of Victoria.
MILAN .. Royal Lombard Institution of Sciences.
MISSOURI .. State Survey and University, *Geological Rooms, Columbia, U. S. A.*
MODENA .. Italian Society of Science.
MONTREAL .. Natural History Society.
MUNICH .. Royal Bavarian Academy of Sciences.
NANCY .. Society of Sciences.
NEUFCHÂTEL .. Society of Natural Sciences.
NEW HAVEN, } Connecticut Academy of Arts and Sciences.
 U. S. A. } Editors of Silliman's Journal of Science and Art.
NEW YORK .. State Museum of Natural History.
OXFORD .. Bodleian Library.
 Ashmolean Society.
PALERMO .. Academy of Sciences and Letters.
PARIS .. Polytechnic School.
 Geological Society.
 School of Mines.
 Institute of France.
 National Library.

PARIS	Jardin des Plantes, Library.
PHILADELPHIA	American Philosophical Society.
	Academy of Natural Sciences, per Trübner and Co.
PISA	Tuscan Society of Natural Sciences.
PLYMOUTH ..	Plymouth Institution and Devon and Cornwall Natural History.
PRESBURG ..	Association for Natural History.
QUEBEC	Literary and Historical Society.
ROME	Vatican Library.
	Royal Geological Society of Italy.
ROUEN	Academy of Sciences.
SAN FRANCISCO	California State Geological Society.
ST. ANDREWS	University Library.
ST. LOUIS ..	Academy of Sciences.
ST. PETERSBURG	Imperial Academy.
	Central Physical Observatory of Russia.
	Imperial Russian Mineralogical Society.
STOCKHOLM ..	Royal Academy of Sciences, per Longman and Co., <i>Faternal- row, London</i> ; and Sampson and Wallis, <i>Stockholm</i> .
	Geological Survey of Sweden.
STRASBURG ..	Society of Natural Sciences.
STUTTGART ..	Association for Native Natural History.
TORONTO, C.W.	Canadian Institute, per Thomas Henning, Esq.
TOULOUSE ..	Academy of Sciences, Inscriptions, and Literature.
TRURO	Royal Institute of Cornwall.
TURIN	Royal Academy of Sciences.
UPSALA	Royal Society of Sciences.
VIENNA	Imperial Academy of Sciences.
	The Editor of the "Annual of the Imperial-Royal Geological Institute."
	Imperial-Royal Zoological and Botanical Society, per Braümüller and Co., <i>Vienna</i> .
WASHINGTON	Smithsonian Institution Library, per Mr. W. Wesley, 28, <i>Essex- street, Strand, London</i> .
WINDSGR ..	Royal Library.
ZURICH	Natural History Society.





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